ACHINE DESIGN

ANUARY 1955

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DC CONTACTORS

perform wide range of control functions

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CONTROL

Type 264 single-pole general-duty contactor

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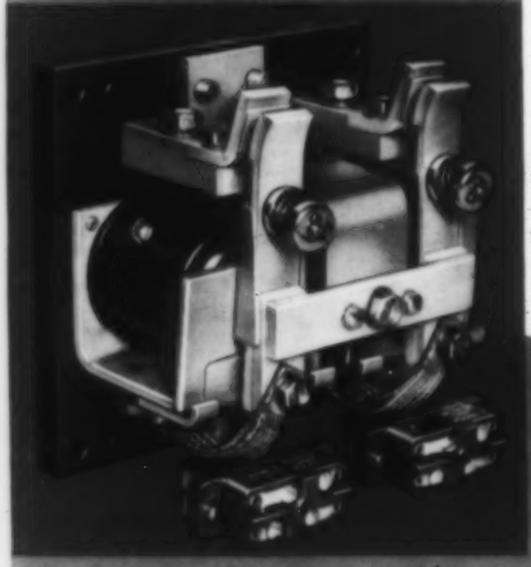
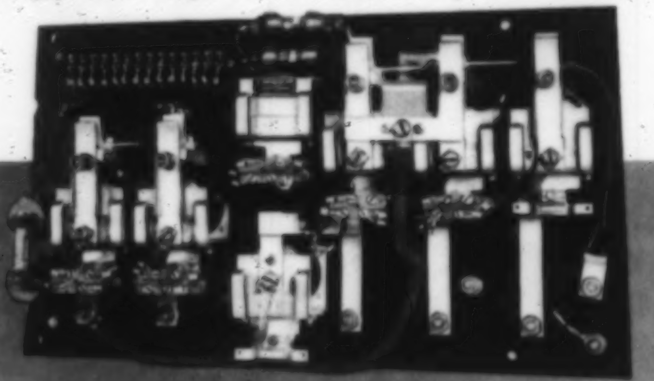


Type 264 reversing general-duty contactor



Panel shows how both single-pole and reversing contactors may be mounted to perform several functions.

A-4400

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THE PROFESSIONAL JOURNAL
FOR ENGINEERS AND DESIGNERS

MACHINE DESIGN

JANUARY 1955
Vol. 27—No. 1

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Over the Board

Out of This World

At year end every magazine likes to look back on its past year's performance. In terms of bulk alone, the record is quite impressive for MACHINE DESIGN. In the twelve months of 1954, each reader received almost 5000 pages, and weight of the twelve issues was about 26 pounds. Over 121 million total pages were mailed, and about eight railroad freight cars, piled full, would have been needed to ship these copies. Piled up in a single stack, the magazines mailed during 1954 would have reached beyond the earth's atmosphere, and farther than the maximum height reached by the latest two-stage rocket.

Getting Up Steam

After looking at early proofs of "Rounding Up the 1955 Automobiles" in this month's Engineering News Roundup, we started wondering what happened to the old steam car. After checking a bit, we came up with a list of steam automobiles noted by Crosby Field in a recent ASME talk. Steam cars were on the market as early as 1860 (the Roper) and as late as 1934 (the Delling). During this period, 83 companies manufactured steam autos. And some of the names were really unusual. Along with the generally known Stanley Steamer were names with an engineering flavor, like the Gearless, the Locomobile and the Tractobile; those named geographically, like the Detroit, the New England and the Toledo; and those with such peculiarly descriptive appelations as the Crouch, the Kidder, the Baker and the Boss.

Too Technical?

Sometimes MACHINE DESIGN articles get pretty technical. "Why can't you simplify your articles and make them more readable?" some readers ask. As editors we can appreciate this point of view—and we try to make each article as readable as possible. But you can't leave out technical terms, since they are the common language of engineering. But we thank our collective lucky stars that we're not faced with some of the problems of our editorial confreres in Germany. Recently, we ran across some German automatic control terms defined by D. W. Pessen of Minneapolis-Honeywell. Some of them are enough to set the most experienced editor's brain reeling. An analog computer, for instance is a *Stetigrechner,* and "transmission lag" is a tongue-twisting *Ubertragungsverzogerung.* But the real jawbreaker is *Regler mit Stellgeschwindigkeitszuordnung,* which is defined as an "integral or floating-action controller."

This Month's Cover

Filters were used 4000 years ago to filter medicines, wine and beer. Although still used for these fluids today, filters are apt to be more familiar to engineers as cleaners for oil, hydraulic fluid or gasoline. These engineering types of filters, discussed in the article on Page 167, are the subject for George Farnsworth's unusual cover.

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Published on the seventh of each month. Subscription in the United States, possessions, and Canada: One year $10. Single copies, $1.00. Other countries one year, $20. Copyright 1955 by The Penton Publishing Company. Accepted as Controlled Circulation publication at Cleveland, Ohio.

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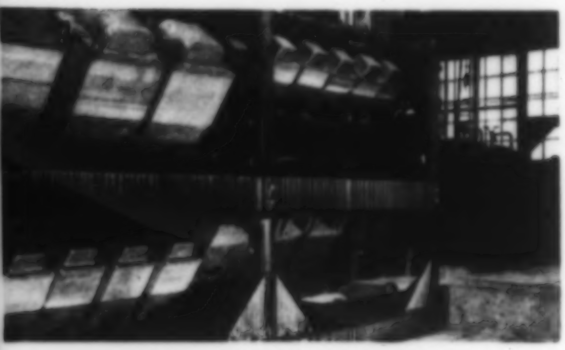

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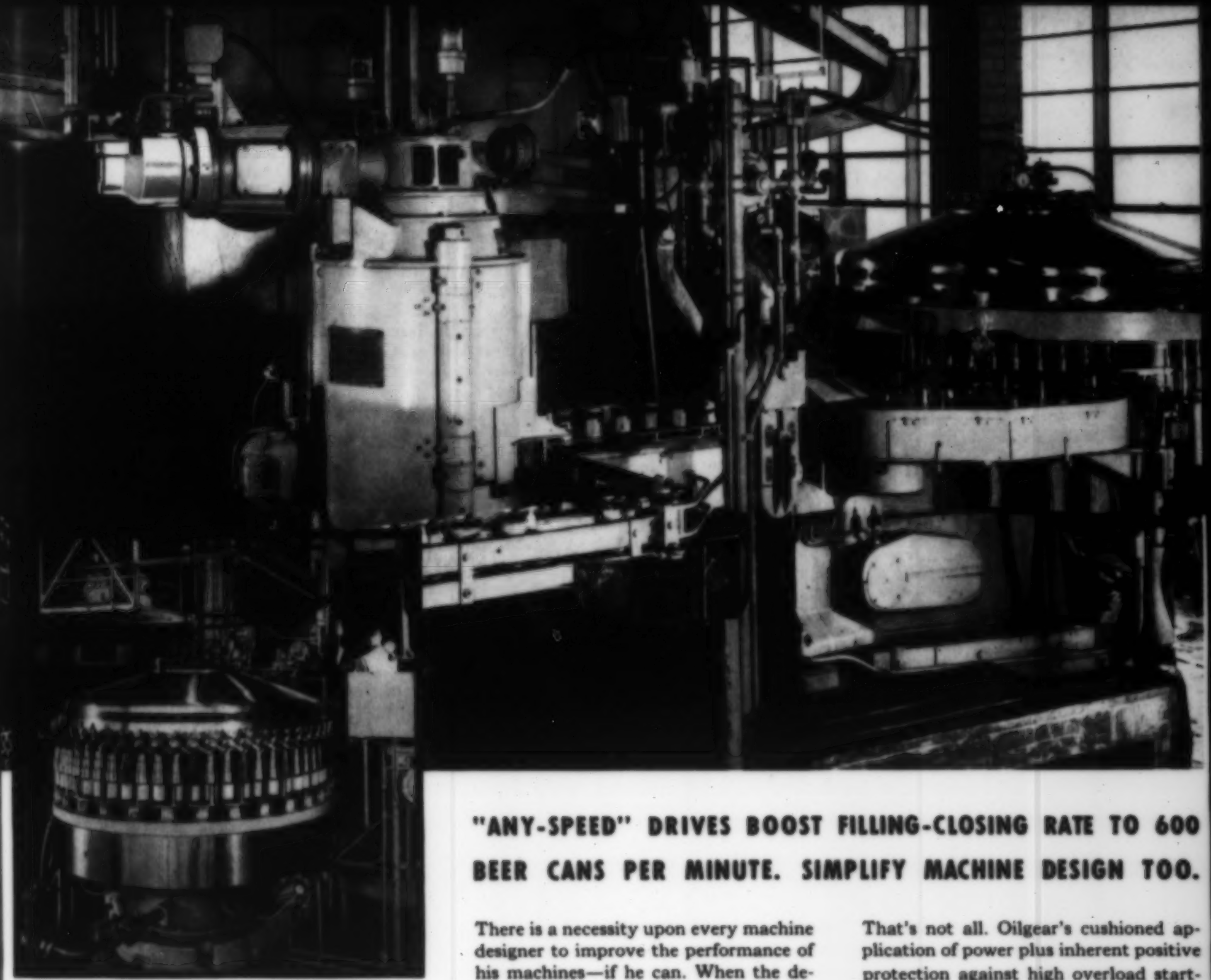

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PRECISION SOLUTION

to combination loads!

NEW DEPARTURE BALL BEARING
FACTS
NUMBER 1

Combinations of axial and radial loads on moving parts present a constantly recurring problem to the engineer and designer. And this problem is further multiplied by today's demand for lasting precision with minimum service and adjustment. Naturally, too, every designer strives for a basic simplicity in his product that means manufacturing economy.

A Job For Bearings

The work of holding moving parts in a predetermined position or location must fall on the bearings. How well they maintain the desired accuracy . . . and for how long . . . determines their value.

Because of certain inherent qualities, ball bearings offer outstanding advantages that can be found in no other type of bearing.

Basic Advantages Of The Ball

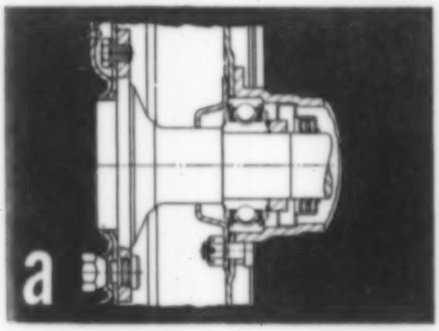
The ball is a unique shape. It rolls naturally in any direction. It has no weakest point. In combination with raceways of proper design, it can resist all loads.

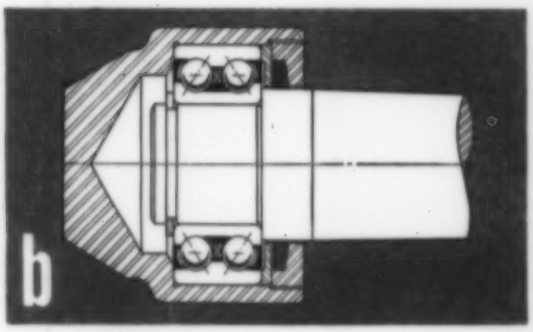
Parts are held rigidly in position and, since wear is virtually nonexistent in properly enclosed ball bearings, no adjustment is required. Regardless of the angle at which load is applied, a uniform and readily calculable resistance is presented, and bearing life may be accurately predicted. Ball bearings thus may be readily selected to match the service expectancy of the machine in which they are used.

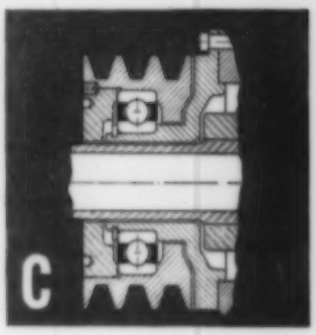
New Flexibility For Machines

Through this ability to resist all loads, machines using ball bearings can be operated in any position and at high or low speeds. One compact ball bearing can often replace an installation of two other bearings of different load-carrying abilities.

New Departure will welcome the opportunity to work with you on any bearing problem. Remember, there is no substitute for experience—and for more than 50 years New Departure has led in bearing design, testing and manufacture.







A. In this automobile rear wheel mounting the axle shaft is located against thrust in both directions by a single New Departure Sealed-for-Life bearing. Adjustments and need for relubrication are eliminated. Here are definite advantages over other types of anti-friction bearings.

B. In applications subject to heavy thrust, such as live centers, double row New Departure *ball* bearings give excellent performance. These bearings may be internally preloaded for maximum resistance to deflection under load. In this example, the center nose is ground after assembly.

C. In applications such as pulleys, New Departure radial, non-loading groove bearings may be used singly for radial, thrust or combined loads according to rated capacities. Thrust and radial capacities are approximately equal.

For complete information send for Booklet BA-1

NEW DEPARTURE
BALL BEARINGS

NOTHING ROLLS LIKE A BALL

NEW DEPARTURE • DIVISION OF GENERAL MOTORS • BRISTOL, CONN.

Engineering News Roundup

Russians Building Big Engineer Supply

American supremacy in science and technology is seriously threatened by a rapid build-up in the supply of engineers in Russia. So warned Dr. J. T. Rettaliata, president of Illinois Institute of Technology recently.

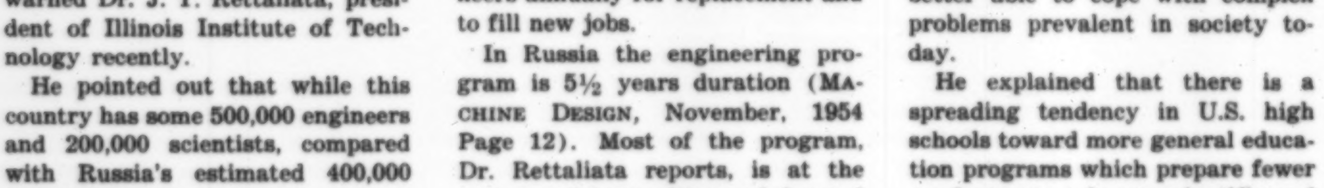
He pointed out that while this country has some 500,000 engineers and 200,000 scientists, compared with Russia's estimated 400,000 and 150,000, the Soviets have been rapidly expanding training in these fields.

"From 1951 to 1954," he said, "the number of Russian engineering graduates totaled 154,000 compared with our 116,000 for the same years—an average of 38,500 a year against our 29,000." He estimated that United States industry currently needs 30,000 engineers annually for replacement and to fill new jobs.

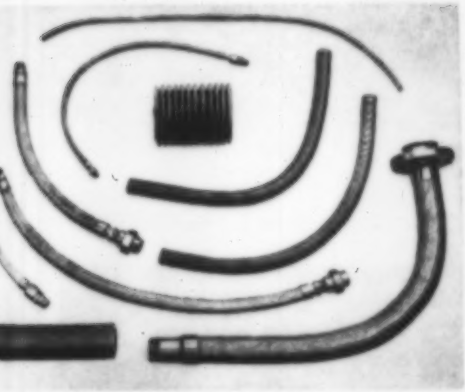
In Russia the engineering program is 5½ years duration (MACHINE DESIGN, November, 1954 Page 12). Most of the program, Dr. Rettaliata reports, is at the expense of humanities and devoted rather to narrow specialization. In major subject matter, education is equivalent to beyond the master's degree level here.

In the United States, the objective is to prepare the scientist and engineer for civic as well as professional responsibilities. More of the humanities and liberal studies are included to produce engineers better able to cope with complex problems prevalent in society today.

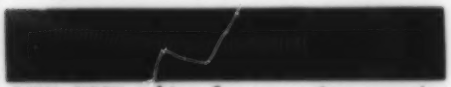
He explained that there is a spreading tendency in U.S. high schools toward more general education programs which prepare fewer graduates to take up scientific and engineering studies in college.



WORLD'S FASTEST helicopter, powered by a gas turbine, recently broke the world's helicopter speed record at 156.005 mph. Built by Sikorsky, the plane is powered with a Continental-Turbomeca XT-51-T-3, right, rated at 425 hp. Shortly after its record-breaking speed run, the plane established a new helicopter altitude record of 24,500 ft



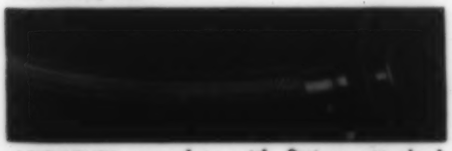
WIDELY USED in processing of food and chemicals, American Flexible Stainless Steel Tubing is engineered to design requirements.



OPEN PITCH tubing for conveying corrosive liquids and gases, exhaust, hot air, etc. under infrequent movement conditions.

STAINLESS STEEL BRAID gives extra strength to tubing for high pressure service.

CLOSE PITCH tubing for extra flexibility, frequent movement, vibration, compressions, extension, etc.



ASSEMBLIES, complete with fittings attached, manufactured to your specifications.

American Flexible Stainless Steel Tubing meets tough design "specs"

- **Conveys corrosive gases and liquids at high temperatures—high pressures**
- **Stands up under continuous flexing**
- **Absorbs severe vibration**
- **Compensates for misalignment**
- **Takes movement and offset motion**

Today industry looks to "American"—a leader for over forty years in the manufacture of flexible metal hose and tubing—as a dependable source for flexible *stainless steel* tubing. This tubing is specially engineered and manufactured to give desired flexibility with greatest durability.

American Flexible Stainless Steel Tubing is annularly corrugated, and is made in both open and close-pitch construction. It is available in Types 316 and 321, ranging in size from ¼" I.D. through 4" I.D. Assemblies are made up with or without wire braid covering to meet most industrial working pressures. American stocks a line of standard fittings. These are attached to the tubing in our own plant by Heliarc welding or silver brazing.

Send us details of your connector problem. "American" engineers can help you solve it.

WHEREVER CONNECTORS MUST MOVE

AMERICAN

flexible metal hose and tubing

an ANACONDA® product

FREE BOOKLET!

Gives engineering data on construction and types of American Flexible Stainless Steel Tubing. Includes information on fittings. Write today for your free copy.

The American Brass Company, American Metal Hose Branch, Waterbury 20, Conn.

Please send me Bulletin STC-1 on American Flexible Stainless Steel Tubing.

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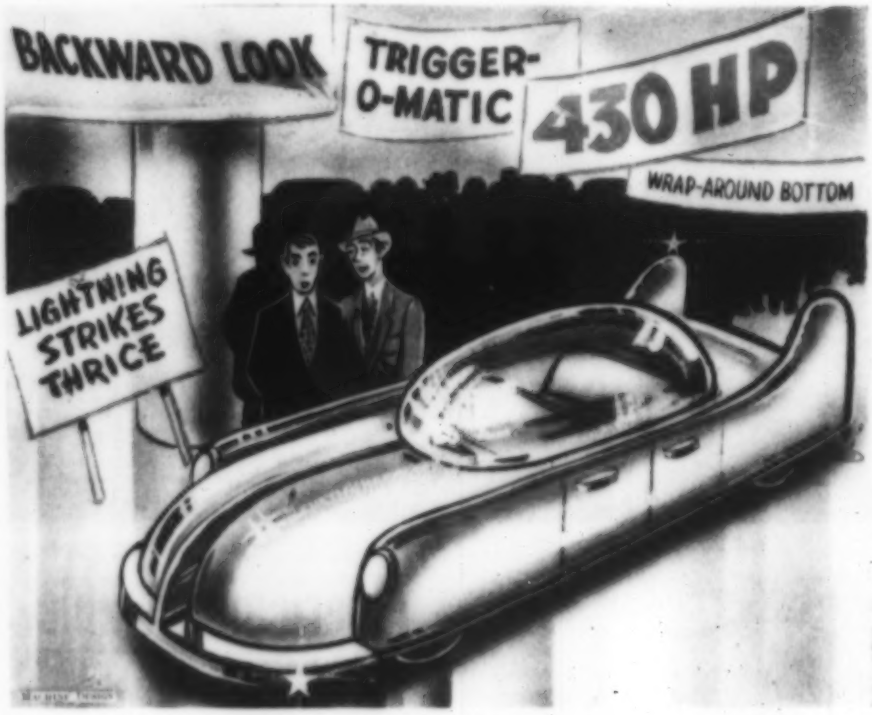
CITY.............................**ZONE**....**STATE**..........

[illegible]

Rounding Up the 1955 Automobiles

A "wrap-around" new look, tubeless tires, and more horsepower are being played up by the 1955 auto makers. Big question in the designers' minds must have been whether to incorporate that "Jaguar dip" or stick to an American streamline shape. In most cases a compromise was reached that falls in the category of someone sticking his big toe in the bath water to see if it's too hot. Of the big three, General Motors has actually incorporated a "semi-dip" on all its models. Chrysler and Ford merely acknowledge it by giving the customer a choice. In some of their more expensive models, a compound-shaped strip of chrome is added to simulate that continental look.

Improved design, combined with 4-barrel carburetors and dual exhausts, is stepping up horsepower. Generally, about 100 hp has been added to most of the engines in the past few years. Not for speed, say the builders, but for that extra reserve power for passing. What effect all this will have on gas consumption remains to be seen and felt.



"That's great, but how is it on gas?"

STUDEBAKER

Studebaker has stepped up engine horsepower to 175 with its "Wildcat" V-8. A four-barrel carburetor is standard on the "Wildcat," but a mechanical arrangement provides 2-barrel carburetion at cruising speeds.

Featuring the shortest stroke, 2$\frac{13}{16}$ inches, of any automobile engine for 1955, the new Pacesetter V-8 is rated at 140 hp. An L-head 6-cylinder engine, rated at 101 hp is also available.

Studebaker's President line is being reintroduced as a luxury line. Commander and Champion models are continued as before.

Engine Specifications

	Victory-6	Pacesetter	Wildcat
Type	L-head, in-line	OHV, Vee	OHV, Vee
No. cyls.	6	8	8
Bore & stroke (in.)	3 x 4$\frac{3}{8}$	3$\frac{9}{16}$ x 2$\frac{13}{16}$	3$\frac{9}{16}$ x 3$\frac{1}{4}$
Displ. (in.^{3})	185	224	259
Comp. ratio	7.5 to 1	7.5 to 1	7.5 to 1
Bhp, max	101 @ 4000	140 @ 4500	175 @ 4500
Torque, max (lb-ft)	152 @ 1800	202 @ 2800	250 @ 3000

Size and Weight

	Champion	Commander	President
Wheelbase (in.)	116½, 120½*	116½, 120½*	120½
Length (in.)	202.25	202.25	206.25
Width (in.)	69.5	69.5	69.5
Height (in.)	60.0	60.0	60.0
Weight (lb)	2930	3236	3321

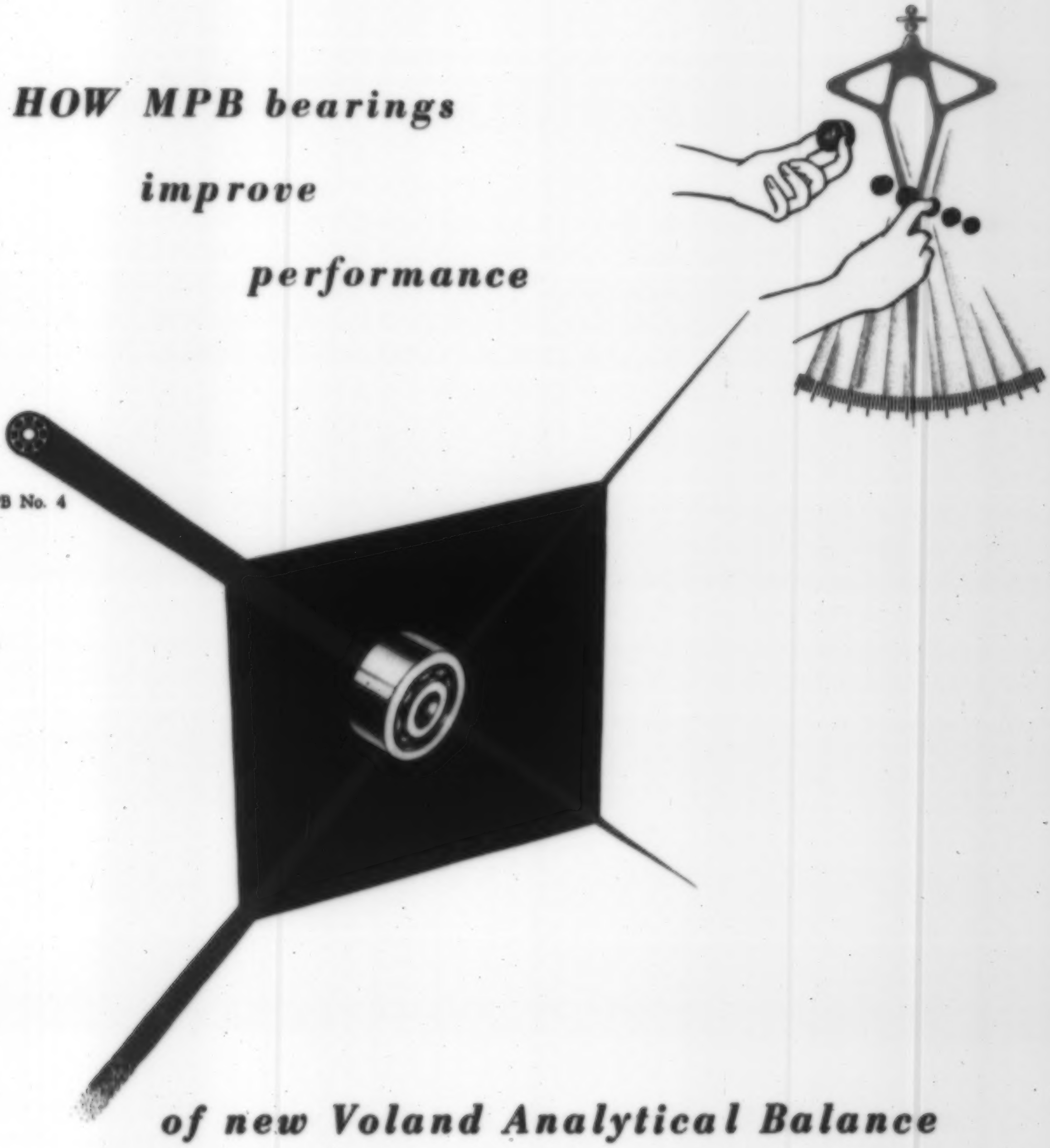
---

* Station Wagons and Sedans—116½ in. wheelbase; hardtops and 5-passenger coupes—120½ in. wheelbase. Dimensions and weight given for 4-door sedans.

MERCURY

Mercury, like Ford, also introduces a new line for 1955. Mercury's Montclair pushes the Monterey line down into the

HOW MPB bearings improve performance



ACTUAL SIZE MPB No. 4

of new Voland Analytical Balance

OPERATING CONDITIONS: MPB bearing serves as anti-friction cam follower on manually operated arrestment control shaft . . . bearing transmits precise action, produces natural "operational feel". CRITICAL: reduced friction . . . accurate bearing concentricity which permits close, accurate alignment of mating parts. RESOLVED: by use of MPB No. 4 Radial Ball Bearing.

Use of MPB miniature ball bearings in the new Voland Analytical balance permits greater operating sensitivity than ever before possible. Bearings concentricity — critical in this application — is held to .0002 TIR. The MPB bearing used in this balance is rated to carry a radial load of over 3 lbs. at 60,000 r.p.m.

In new designs — or in improvement of existing designs — you can count on MPB bearings to provide outstanding performance, accuracy, and reliability. For full information, write on your letterhead, for MPB catalog 54.

Miniature *Precision* Bearings, Incorporated

104 Carpenter St., Keene, N. H. — Western Office & Plant: Santa Barbara Airport; Goleta, Calif.
Woodland 8-8441

middle price class. Sleeker roof lines and somewhat different trim characterize the new series.

Overall height of the cars is lower. Montclair models are about 2½ inches lower than the 1954 Mercurys, while the Monterey and Custom series are about 1 inch lower. Wheel base has been increased to 119 inches. Wrap-around windshields and a redesigned dash add to Mercury's 1955 look.

Engine horsepower has been stepped up, following the general trend. Two overhead valve V-8's are rated at 188 and 198 hp. Dual exhausts and a 4-barrel carburetor are standard equipment on the Montclair and Monterey series. New 18-mm spark plugs feature a larger air gap between the insulator and outer shell.

Engine Specifications

	Custom and Monterey	Montclair
Type	OHV, Vee	OHV, Vee
No. Cyls.	8	8
Bore & stroke (in.)	3.75 x 3.3	3.75 x 3.3
Displ. (in.^{3})	292	292
Comp. ratio	7.6 to 1	8.5 to 1
Bhp, max	188 @ 4400	198 @ 4400
Torque, max (lb-ft)	274 @ 2500	286 @ 2500

Size and Weight

	Custom and Monterey	Montclair
Wheelbase (in.)	119	119
Length (in.)	206.3	206.3
Width (in.)	76.4	76.4
Height (in.)	61.2	58.6
Weight (lb)	3500	3490

Merc-O-Matic automatic transmission has been redesigned to increase its capacity. A specially designed kickdown has been added for fast takeoff in low gear with the selector in the drive position. A new hydraulic control system has been developed to improve performance of band and clutch engagement.

Powered lubrication can be added as optional equipment on the 1955 Mercurys. Pressing a button on the instrument panel lubricates all chassis bearings.

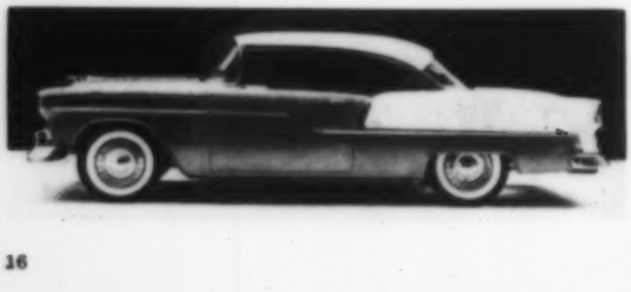
CHEVROLET

Chevrolet for 1955 has undergone a complete face-lifting. Increased glass area, higher horsepower engines, addition of a V-8 engine to the line and a 12-volt electrical system are among the newly added features.

Engine Specifications

	Conventional	Powerglide	Turbo-Fire
Type	OHV, in-line	OHV, in-line	OHV, Vee
No. cyls.	6	6	8
Bore & stroke (in.)	3$\frac{9}{16}$ x 3$\frac{15}{16}$	3$\frac{9}{16}$ x 3$\frac{15}{16}$	3$\frac{3}{4}$ x 3
Displ. (in.^{3})	235.5	235.5	265.0
Comp. ratio	7.5 to 1	7.5 to 1	8.0 to 1
Bhp, max	123 @ 3800	136 @ 4200	162 @ 4400*
Torque, max (lb-ft)	207 @ 2000	209 @ 2200	257 @ 2200

* Rated 180 hp @ 4600 with 4-barrel carburetor and dual exhausts.



Size and Weight

Wheelbase (in.)	115
Length (in.)	195.6
Width (in.)	74.0
Height (in.)	62.1
Weight (lb)	3220*

* With automatic transmission.

A 6-cylinder engine for conventional shift is rated at 123 hp. To provide the higher horsepower required for Powerglide, a 136-hp 6-cylinder engine is available. An overhead valve V-8, called the Turbo-Fire, develops 162 hp. With a 4-barrel carburetor and a dual exhaust system added to the V-8, a horsepower rating of 180 can be achieved, according to Chevrolet.

Fresh air is brought in through cowl ducts, eliminating air ducts through the engine compartment. Ammeter and oil pressure gages have been replaced by indicator lights.

FORD

New wrap-around windshields and a lower silhouette characterize all three of the 1955 Ford lines. Styling, according to Ford, has been inspired by the Thunderbird.

Big feature for 1955 is the introduction of the new Fairlane series as Ford's highest-priced line. A Crown Victoria features a chrome arch extending over the top. It comes with either an all-steel top or the transparent plastic roof. The new Crown Victorias are less than 5 feet high or about 2½ inches lower than the 1954 Fords.

Engine Specifications

	Six	Eight	Special Eight
Type	OHV, in-line	OHV, Vee	OHV, Vee
No. cyls.	6	8	8
Bore & stroke (in.)	3.62 x 3.60	3.62 x 3.30	3.62 x 3.30
Displ. (in.^{3})	223	272	272
Comp. ratio	7.5 to 1	7.6 to 1	8.5 to 1
Bhp, max	120 @ 4000	162 @ 4400	182 @ 4400
Torque, max (lb-ft)	195 @ 1200-2400	258 @ 2200	268 @ 2600

Size and Weight

	Mainline	Customline	Fairlane
Wheelbase (in.)	115.5	115.5	115.5
Length (in.)	198	198	198
Width (in.)	76	76	76
Height (in.)	61	61	61
Weight (lb)	3106	3236	3268

Three new engines featuring 18-mm spark plugs are offered this year. A new 182-hp V-8 is available only on the new Fairlane and station wagon series. Dual exhausts and a 4-barrel carburetor are standard equipment. A lower powered 162-hp V-8 is also available. Ford's 6-cylinder engine rated at 120 hp now boasts a higher compression ratio.

A NIGHTMARE TO MACHINE

4½°
.105
.100
.105
.101
.156
.151
.1050
.1035
SCALE 4:1

. . . A SIMPLE, INEXPENSIVE JOB FOR BOUND BROOK

You don't need a time-study crew to tell you this part might cost you its weight in gold, produced the old-fashioned way. When your men machine away alternate teeth, every motion costs you money. Bound Brook produces bronze and brass gears and other parts like these by improved processes of powder metallurgy . . . and in volume at a fraction of the cost of machining. Finished parts are smooth, burr-free; well within the tolerances required; identical in strength and density. In producing parts of metal powder results depend upon the skill, the equipment, the capacity, and management's ability to keep delivery-date promises. Write or wire Bound Brook direct, or telephone the Bound Brook man nearest you to learn why Bound Brook can give you the results you want, lower costs; faster production; with parts of bronze, brass or iron, or with bearings of bronze or iron.

2

BOUND BROOK

BOUND BROOK OIL-LESS BEARING CO., EST. 1883, BOUND BROOK, N. J.

Pioneer in

POWDER METALLURGY BEARINGS + PARTS

Improved riding qualities are said to result from tilting the ball-joint front suspension. Named the Angle-Poised Ride, this new design is said to absorb road shocks from the front as well as up and down.

Larger brakes, a redesigned instrument panel and 49 color combinations round out Ford's 1955 features.

PONTIAC

Pontiac for 1955 claims 109 new features. Among these is a new 180 hp V-8 overhead-valve engine. Several new features highlight the new engine. Reverse-flow gusher valve cooling feeds water directly from the radiator to the cylinder head and from there to the cylinder block. A completely machined combustion chamber promises to result in a smoother running engine. Ball-pivot valve rocker arms are said to quiet valve operation and require no manual adjustment.

Redesigned instrument panel features the new safety-arc speedometer. A cowl-wire air intake below the wrap-around windshield is designed to provide fume-free air to the passenger compartment.

Engine Specifications

Type	OHV-Vee
No. cyls.	8
Bore & stroke (in.)	3¾ x 3¼
Displ. (in.³)	287.2
Comp. ratio	8.0 to 1
Bhp, max	180 @ 4600
Torque, max (lb-ft)	264 @ 2400

Size and Weight

	Chieftain	Star Chief
Wheelbase (in.)	122	124
Length (in.)	203.2	210.2
Width (in.)	75.4	75.4
Height (in.)	60.5	60.5
Weight (lb)	*	*

* Not available.

LINCOLN

Lincoln's 1955 feature seems to be the lack of the popular wrap-around windshield. Instead, Lincoln engineers have added a new automatic transmission, a new 225-hp engine, and a powered lubrication system.

One-shift operation has been incorporated in a new Lincoln automatic transmission for extra fast take-off. A throttle kickdown has been incorporated for greater flexibility. Called the Turbo-Drive, the new transmission is entirely air-cooled.

A redesigned 4-barrel carburetor and a new high-lift, high-torque camshaft contribute to the increased horsepower of Lincoln's overhead valve V-8. Displacement has been increased from 317 to 341 cu in. this year. This increase is probably the biggest factor contributing to Lincoln's increased horsepower. All Ford-made engines this year, including the Lincoln, have incorporated the new 18-mm spark plugs.

Engine Specifications

Type	OHV, Vee
No. cyls.	8
Bore & stroke (in.)	3.94 x 3.50
Displ. (in.³)	341
Comp. ratio	8.5 to 1
Bhp, max	225 @ 4400
Torque, max (lb-ft)	332 @ 2500

Size and Weight

Wheelbase (in.)	123
Length (in.)	215.6
Width (in.)	77.6
Height (in.)	62.7
Weight (lb)	4275

Powered lubrication is available as optional equipment. This feature provides constant lubrication of the chassis, suspension and steering systems. Merely pressing a button on the dash once a day shoots the necessary lubricant through nylon tubing to the proper points. A green light indicates when the job is completed.

Riding comfort is said to be improved by mounting the rear shock absorbers at a more horizontal angle and increasing the rear tread. Overall length of the Lincoln has been slightly increased.

To be continued in February

No More Bumps At Rubber Crossing

Another irritation of motorists promises to be eliminated with the development of the world's first rubber railroad crossing. Bumps and jolts experienced when crossing railroads may be a thing of the past if a newly developed rubber makes a successful substitute for wood-planked crossings.

Developed by Goodyear, the rubber slabs measure 36 by 9 inches. Slightly over 3 inches thick the slabs have a heavy gage steel sheet sandwiched between them. Wood planking placed over the ties supports the rubber and each slab is fastened down with lag

Workmen installing a rubber slab on the world's first rubber railroad crossing in Akron. Slabs were designed to form a watertight seal to the rails to prevent water seepage to the ties below

screws 12 inches long.

Sealing action of the rubber to the rails is another feature of the development. Tapered flanges on the rubber slabs form a watertight wedge to the rail. Seepage of water down to the ties is prevented, and deterioration of the ties is expected to be greatly reduced. Goodyear engineers expect the installation to last indefinitely.

Special wear and skid-resistant rubber compounds were molded into a diamond design similar to tire tread design. The installation is expected to find the most use at heavily traveled grade crossings.

Heat Now Plagues Jet-Plane Designers

After going through the sound barrier, high-speed aircraft have reached another barrier—the thermal barrier. Heat problems, brought about by friction of air on the plane's surfaces, are giving designers new headaches.

According to technical papers presented at the recent annual meeting of the American Society of Mechanical Engineers, research on these high-heat problems lags behind the design of the aircraft that fly that fast.

Among the headaches encountered are the fact that aluminum melts at mach 5 and steel melts at mach 6. Increased weight necessary to make an aircraft structurally safe at 800 F might render the plane impractical. Mechanical properties of metals decrease rapidly as temperature goes up. It was emphasized that research on new high-temperature metals is needed.

Two approaches to the design of high speed aircraft are considered. One is to design cooling systems to cool specific parts; the other is to design the plane to endure high temperatures.

Designers may have to tag a definite lifetime on certain parts. It may be necessary to design parts that will be replaced after flights of a certain duration.

Nickel Coating Helps Solder Brass

Recent tests conducted by the Tin Research Institute show that solderability of brass may be greatly improved by a flash coating of nickel before tinning.

Previously, electrotinned brass parts have shown marked deterioration in solderability after a few months' storage. In order to insure against such deterioration for periods of up to 1 year, a tin coating of at least 0.0005-inch has been applied.

Findings now indicate that with a nickel flash of 0.0002-inch, parts remain in solderable condition for over a year. In fact, no signs of deterioration have been noticed, and parts apparently will remain in this condition permanently.

Certain difficulties encountered in tinning brass by dipping may also be eliminated by utilizing this method. Solder in a dipping bath picks up zinc and fails to give a clean, bright and smooth coating. By precoating the brass with a

(*Continued on Page* 24)

When

SPECIFY REPUBLIC

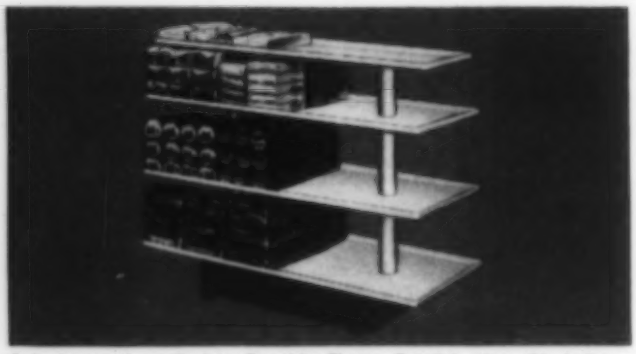
This rear axle assembly must withstand shock and vibration at high speeds. Republic "Nylok" Nuts are used to assure positive locking even under severe vibration. The nylon plug in one face forces the nut tight against the opposite threads of the stud as the nut is turned on.

Republic "Nylok" Nuts lock whether seated or not. They go on easily. Either end is up. Feed them automatically at full production speed. Or manually for piece-work. No special tools, lubricants or techniques are needed.

They cut maintenance costs, too. Republic "Nylok" Nuts are easily backed off for inspection of parts. And, then can be re-used.

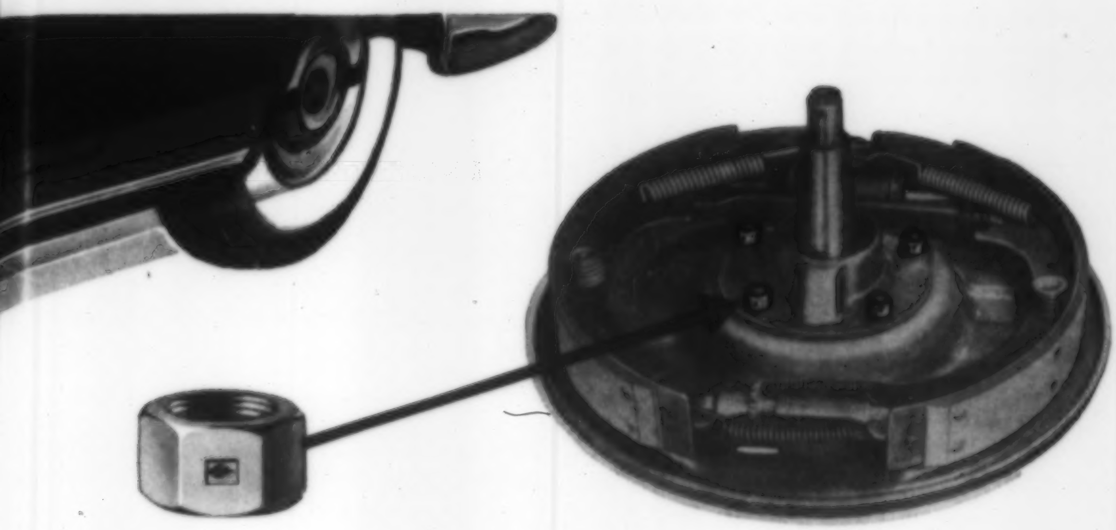
REPUBLIC

World's Widest Range of Standard



Baked-enamel applied to Republic Electro Paintlok gives this bakery goods display a customer-attracting appearance and longer service life. These zinc-plated steel sheets are chemically treated to take paints, lacquers, synthetic enamels—and hold them for years. If you paint on steel, consider Electro Paintlok for making your fabricated steel products more attractive, more serviceable, at less cost.

Revenue increased 15% to 40% when these rental lockers were made from Republic ENDURO Stainless Steel. Yet, costs were only 9% more than for carbon steel, painted. ENDURO's bright, attractive finish generates "sell". No other material offers the designer so many advantages. Republic makes ENDURO in all commercial forms. Republic metallurgists will help you apply its bonus benefits to your product or process.



vibration is a problem...

"NYLOK" NUTS!

12 WAYS BETTER

Assemble from either end • Can be re-used • Non-galling • Best wrenching characteristics • One-piece • Cold-forged • Won't damage threads • No special tools • Lock in any position • No special know-how • No lubricants needed • Ideal for mechanical feeding

SIZES

Finished Series tapped ¼" through 1"
Finished Thick Series tapped ¼" through ½"
Heavy Series tapped ¼" through 1"

Write for a sample indicating size required.

"Nylok"*Nuts are only one of more than 20,000 types and styles of high quality fasteners made by Republic for all industries.

*U. S. Pat. No. 2,462,603 and No. 2,450,694 and pending applications.

STEEL

Steels and Steel Products

These gears were made at less cost from Republic Cold Drawn Special Sections. Much of the machining was eliminated because the sections already were formed to the predominating cross-section of the part. Parts benefit from the increased physicals produced by cold drawing. The bright smooth finish rarely requires further machining. Send samples or blueprints of your parts. We will tell you whether you can save money—and how much—by making your steel parts from Republic Special Sections.

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REPUBLIC STEEL

☐ Please send a sample "NYLOK" Nut Size________
Please send literature on: ☐ Electro Paintlok Sheets
☐ Enduro Stainless Steel ☐ Cold Drawn Special Sections

Name________________________ Title____________

Company________________________________

Address________________________________

City____________________ Zone____ State__________

(*Continued from Page* 21)

nickel flash, the solder bath remains in a usable condition much longer.

SLOW-SPEED PHOTO! This picture shows the high viscosity of a new silicone rubber polymer. According to Dow Corning Corp., the new compound may be mixed to produce silicone rubbers suitable for application as wire and cable insulation. Known as Dow Corning 400 Gum, the polymer is said to be clear, uniform and nontoxic

Previews

What Standards Do You Use?

Standard fits and limits have been prime subjects for engineering discussions (and arguments) for a good number of years. Everyone has his own set of rules, and standardization has progressed at a snail's pace. As the lead article in this issue, Page 138, we present the results of an industry-wide survey by contributing editor Roger Bolz—containing a set of recommendations which seem to fit current industry practices.

In a Spin Over Stainless

Beginning on Page 148, A. Roland Teiner spins a tale about spinnings that may offer help for certain difficult-to-produce components. Usually considered a hand production process, spinning is well suited for small quantities, but can be effectively used for larger quantities of certain types of parts. Spun stainless parts offer particular advantages, and certain of the stainless alloys are economical to produce. Might give the article a whirl!

Getting Geared Up

In certain applications, precision gearing is a "must"—backlash, and position or velocity-ratio errors, may be troublesome. How to cope with these problems in design is discussed by George Michalec in a series of articles beginning in this issue, Page 154. Many of the points have implications in the design of all kinds and sizes of gearing.

Keep It Clean!

Over 4000 years ago filters were used to preserve the clarity and purity of wine, medicines and beer. Although they are still used for these products, today's filters are highly engineered gadgets with controlled porosity and carefully planned applications. The major factors involved in filter selection are outlined in the Kovacs and Wolk article on Page 167.

Twelfth annual Machine Design Conference sponsored by the Cleveland Engineering Society will be held at the Society's headquarters on February 7, 1955. For further details on the one-day meeting, write to Cleveland Engineering Society, 2136 East 19th St., Cleveland 15, O.

Survey Says Things Look Good for 1955

Manufacturers expect to add to their payrolls during the first quarter of 1955. Apparently, says a new Dun & Bradstreet survey, they expect a rising trend of new orders.

According to the report, 51 per cent of manufacturers of durable goods expect increases in orders. Decreases are expected by 14 per cent of durable goods producers. Only 9 per cent of manufacturers of nondurable goods expect decreases, while 59 per cent of that group expect increases.

Business men expecting to increase their employees number 14 per cent of the total interviewed. About 7 per cent expect to cut down, while 79 per cent say they will operate with the same number.

This survey, says Dun & Bradstreet, is the first made by the agency in over a year in which the majority of business executives

Miller AIR CYLINDERS

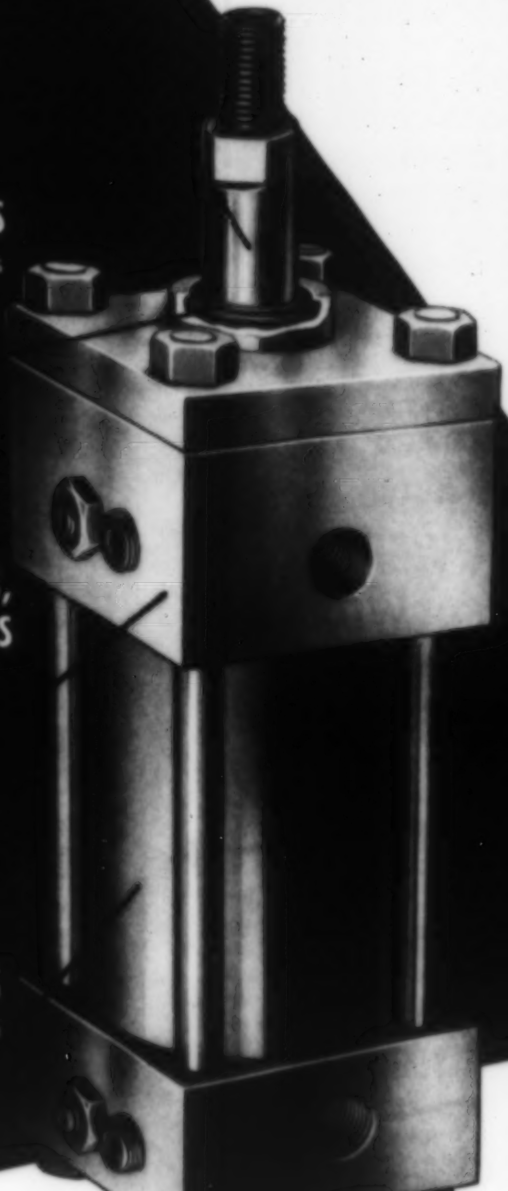
In Thousands of Different Selections For Immediate Delivery!

RD
ROME PLATED
STON RODS
vent Scratch-Damage,
ks and Rust

RT WIPER SEALS
tect Rods, Seals, Bushings

LID STEEL HEADS,
PS and MOUNTINGS
minate Breakage

RASS BARRELS
minate Rust and Corrosion



Rapidly expanding list of quality-famous Miller Cylinders for immediate, off-the-shelf delivery now includes thousands of different, popular selections—both air and hydraulic—cushioned and non-cushioned. Bores up through 8" air, 5" hydraulic. Over 30 different mountings. Strokes up to 18".

Larger bores (up to 20") and longer strokes (up to 22 feet) are available on longer delivery.
Miller Boosters also in stock for immediate delivery.

Write For Catalog and Stock List

WRITE FOR CYLINDER BULLETINS A-105 and H-104

Complete Miller cylinder line includes: air cylinders, 1½" to 20" bores, 200 PSI operation; low pressure hydraulic cylinders, 1½" to 6" bores for 500 PSI operation, 8" to 14" bores for 250 PSI; high pressure hydraulic cylinders, 1½" to 12" bores, 2000-3000 PSI operation. All mounting styles available.

- **MET J. I. C. PNEUMATIC STANDARDS** years before their adoption in 1950.
- **SPACE-SAVING SQUARE DESIGN** originated by Miller in 1945.

SALES AND SERVICE FROM COAST TO COAST

VELAND • YOUNGSTOWN • DAYTON • PITTSBURGH • PHILADELPHIA • TON • HARTFORD • NEW YORK CITY • BUFFALO • ST. PAUL • GRAND IDS • DETROIT • FLINT • FORT WAYNE • SOUTH BEND • INDIANAPOLIS ILWAUKEE • LOUISVILLE • KANSAS CITY • SEATTLE • LOS ANGELES • FRANCISCO • BALTIMORE • DENVER • ST. LOUIS • MOLINE • CHICAGO OUSTON • TORONTO, CANADA and OTHER AREAS

Miller

MILLER FLUID POWER CO.
(Formerly MILLER MOTOR COMPANY)

2006 N. Hawthorne Ave. Melrose Park, Ill.

AIR & HYDRAULIC CYLINDERS • BOOSTERS • ACCUMULATORS
COUNTERBALANCE CYLINDERS

It costs you money to WAIT!

that's the penalty for continuing WASTEFUL and OBSOLETE hand methods that hold down profits and production

Modernize your assembly department with

DPS POWER SCREWDRIVERS and SELECTIVE PARTS FEEDERS

SPEEDIER ASSEMBLY OUTPUT at FAR LOWER COST in 1955 and the years to come

- Proven beyond question, one of the greatest contributions to modern industry, Detroit Power Assembling Equipment demands your immediate consideration. Start now—Share its advantages with the thousands of the nation's prominent users.

DPS BOWL-FEEDERS fill a Special Need!

- In addition to our popular DPS Barrel Feeder, we offer the DPS Bowl Feeder designed to feed light, fragile parts that might not withstand tumbling. Operates on the VIBRATORY PRINCIPLE . . . fully automatic. Provides oriented single line feeding to Grinding, Packaging, Inspection and other automatic machines and operations.

Write today, send sample assembly—Give details!

DETROIT POWER SCREWDRIVER CO.

2801-A W. FORT ST.
DETROIT 16, MICH.

interviewed expect an increase in sales. Also interesting is the fact that more executives are projecting increases than decreases in the forthcoming levels of their inventories.

Hoover Honored As Pioneer Standards Engineer

Herbert Hoover, thirtieth president of the U. S., has been recognized for his pioneering work in standards by the Standards Engineers Society. At the recent third annual meeting of the Society, Hoover, Vice Admiral G. F. Hussey Jr. and the late Dr. Paul Gough Agnew were awarded the society's highest honor, that of Fellow.

Highest Standards Engineers Society award is being presented Herbert Hoover by Wm. L. Healy, president of the Society, while Madhu S. Gokhale, vice president looks on

The citation to Hoover read in part, ". . . he has distinguished himself . . . as protagonist of the principles on which standards operate — efficient production and elimination of waste. He stands before the world . . . as a pioneer Standards Engineer."

New Research lab at Riverside, Calif. for studies related to guided missiles was recently opened by Motorola Inc. Motorola's military work involves radar bombsights, guided missile equipment and specialized devices in military fields.

New Aluminum Alloy Helps Reduce Corrosion

Sacrificial anodes, cut from a specially developed aluminum alloy, have been applied successfully to a ship hull to reduce corrosion according to Aluminum Company of America.

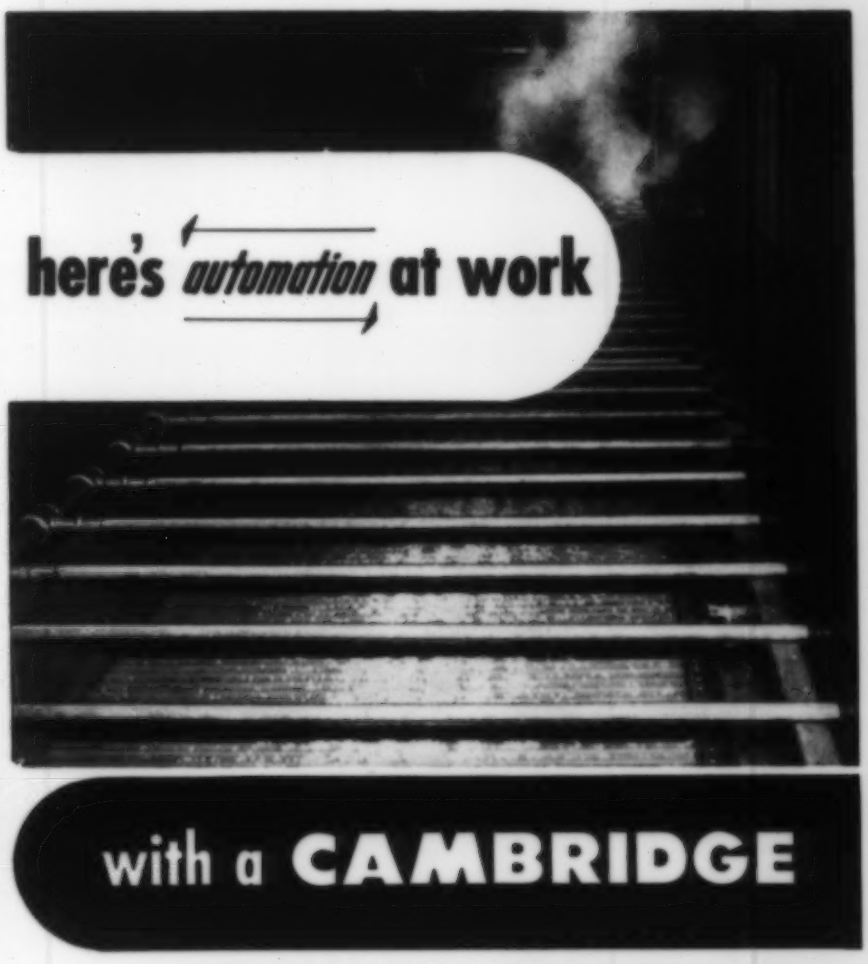
After an 8-month period of service, it was found that the steel which was protected had retained its coating of paint. At this time, the anodes were half consumed. Replacement of the anodes was necessary after a year of continuous service, but the hull was still in good condition.

Patch-like anodes shown here are among the 38 such special aluminum alloy pieces that were installed on this vessel to protect the hull against corrosion from sea water

Other applications for this type of protection may include heat exchangers, storage tanks and various types of condensers. Zinc anodes have also been used for this service.

Versatile hot rolling mill which makes possible the production of strip, rods and bars in one combined layout was recently put into operation by Carpenter Steel Co. The new mill has five finishing points which make possible chang-

(*Continued on Page* 30)



WOVEN WIRE CONVEYOR BELT!

Cut corn is blanched, cooled and frozen on Cambridge Woven Wire Conveyor Belts. Entire operation is *continuous and automatic*, requires no manual handling until discharge from freezing tunnel.

Regardless of whether your process temperatures range from sub-zero to as high as 2100° F . . . whether you use water rinses, acid pickles or other corrosive processes . . . a Cambridge woven wire belt can help you cut manufacturing costs by contributing to automation . . . continuous, automatic production.

Cambridge belts are all metal and can be woven from any metal or alloy. Thus, they are impervious to damage from heat, cold or corrosive conditions. That's why they can be used to process parts or materials while moving from one location to another.

Because of their open mesh construction they permit free circulation of process atmospheres, free drainage of process solutions. They are available in a wide range of specifications for carrying light or heavy loads, large or small parts.

Special raised edges or cross-mounted cleats to hold your product on the belt during flat or inclined movement are easily supplied.

Get the full story—FREE! Learn how Cambridge Woven Wire Conveyor Belts can help you boost efficiency by continuous, automatic production . . . *automation!* Write today for your copy of this manual of belt applications. It's the most complete text available.

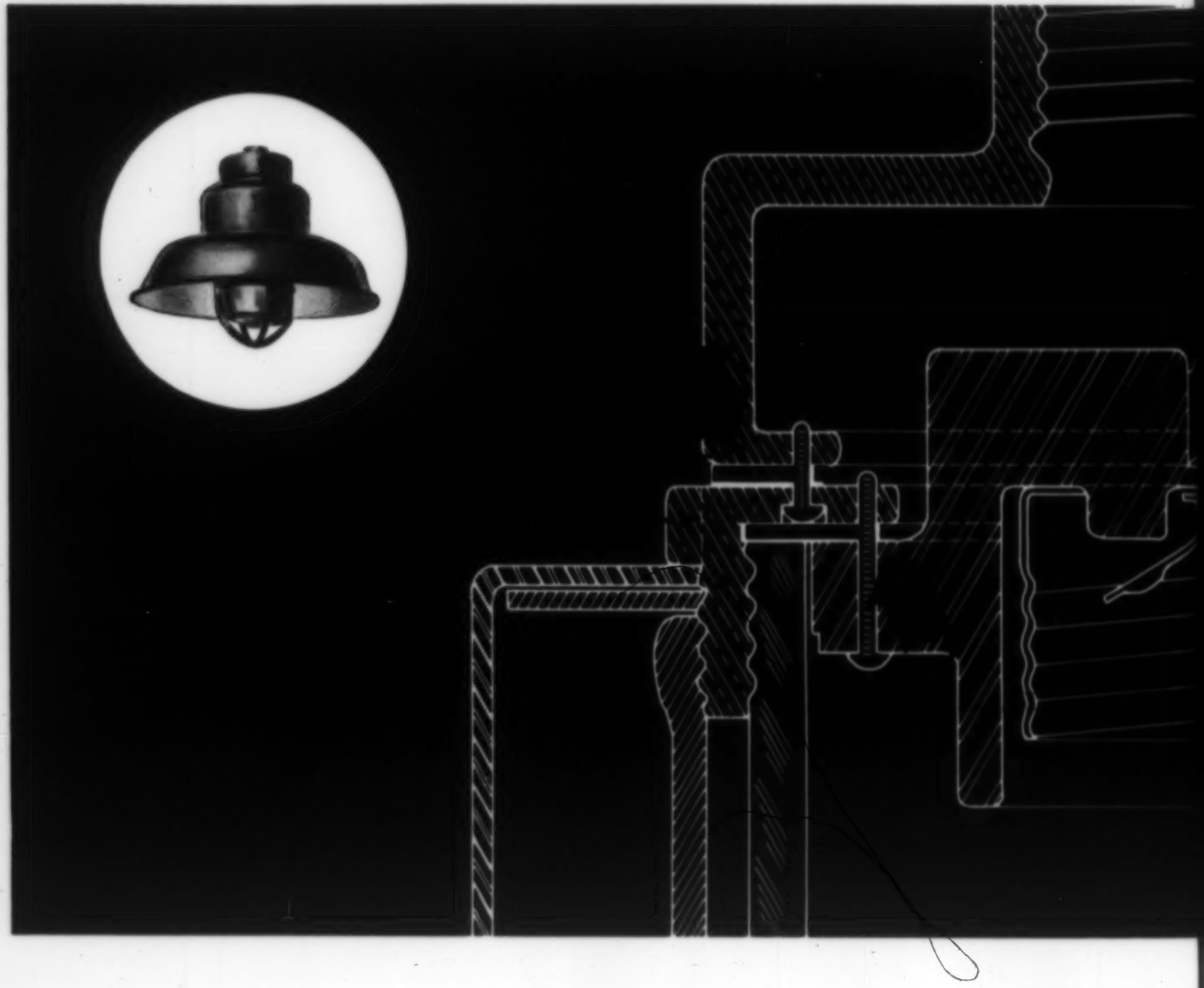
Or, for immediate advice, call in your Cambridge Field Engineer. You can rely on him to make just the right recommendation for you. Look under "Belting-Mechanical" in your classified phone book, or write direct.

The Cambridge Wire Cloth Company

WIRE CLOTH
METAL CONVEYOR BELTS
SPECIAL METAL FABRICATIONS

DEPARTMENT N
CAMBRIDGE 1,
MARYLAND

OFFICES IN LEADING INDUSTRIAL AREAS



improved fiber

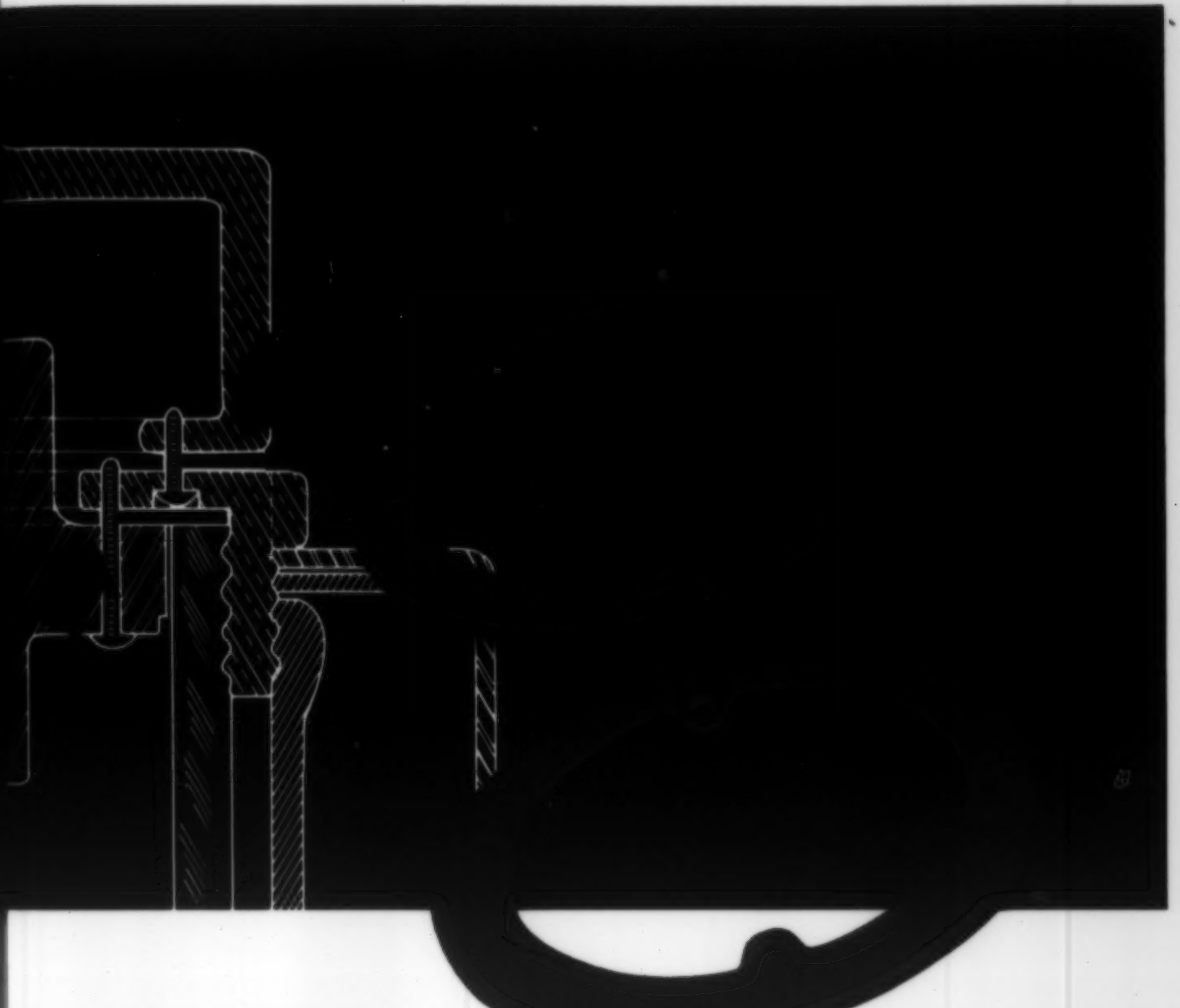
seals vapor out of lamp,

UNIFORMITY. This is a photomicrograph of Accopac in the watery pulp stage of manufacturing. Notice how each fiber has an even coating of latex. This completely uniform distribution of a non-extractable saturant is one of the keys to Accopac's many valuable sealing properties.

A dark residue forming inside the globes of vapor-tight light fixtures was seriously reducing the efficiency of the lamps.

When the manufacturer investigated, he found the cause in the two gaskets being used to seal between the cast aluminum housings and the porcelain receptacle. The 350° F. heat created inside the fixtures by 500-watt bulbs was vaporizing the binder in the gasket material. Though the gaskets still sealed, the vaporized binder condensed inside the globes and formed a residue that dimmed the lamps.

Extensive testing proved that the dimming problem could be solved by using an improved fiber gasket material—Armstrong CS-301 Accopac®. The new material retained its binder, even under the high temperatures generated by continuous, day-and-night operation of the lamp. And, though the flange was held by hand-tight-



gasket

solves serious dimming problem

ened screws, Accopac was compressible enough to provide a lasting vapor seal.

Accopac is well suited to varied sealing conditions because of its unique composition of cellulose fiber, cork, and non-extractable latex binder. The material is remarkably uniform, compressible, and dimensionally stable.

Though a recent development, Accopac already is widely accepted for sealing in consumer and industrial products. Where can you use it? Use Accopac wherever you need extra dependability in a low-cost gasket material.

FREE 24-PAGE GASKET MANUAL—Look in Sweet's product design file for "Armstrong's Gasket Materials"—or write for your personal copy. It contains facts on Accopac and other Armstrong Gasket Materials as well as useful information about gasket design. Write Armstrong Cork Co., Industrial Division, 7001 Dean Street, Lancaster, Pa. **And be sure to specify Armstrong Gasket Materials when you order from a gasket fabricator.**

ARMSTRONG'S
GASKET MATERIALS

Armstrong Accopac

THREAD PRECISION AND UNIFORMITY INSURED WITH CRAMER TIME CONTROL

The threading accuracy of this Steinle Roll Threading Machine is directly related to the highly dependable Cramer Timers which govern the roll slide movements. This carefully predetermined slide travel must be extremely accurate in order to insure thread precision and uniformity.

The Cramer TE Timer, at left, controls the time of dwell of the roll slide in its forward position, while the one at right dictates the exact loading interval. A simple adjustment of either timer permits slow-down or speed-up of the action. Cramer-controlled threading operations on the Steinle machine have been speeded to 40 complete cycles per minute without sacrifice of thread accuracy. There has never been a report of timer failure.

The Steinle Machine is widely used by aircraft manufacturers and others who require extremely accurate threads. Cramer Timers are specified as original equipment for these machines due to their unusually high standards of accuracy and dependability.

If you have a time control problem, Cramer can help you. Write for complete information or technical advice.

The overall accuracy of the Type TE (inclusive of setting) is within 2%, with repeat accuracy within ½ of 1%. The unit is Underwriters' Laboratories listed for use in industrial control equipment.

A "look inside" will show you why you can always depend on Cramer for outstanding performance. Check the "inside" facts, today.

SPECIALISTS IN TIME CONTROL

Cramer TIMING DEVICES

the R. W. CRAMER CO., INC.

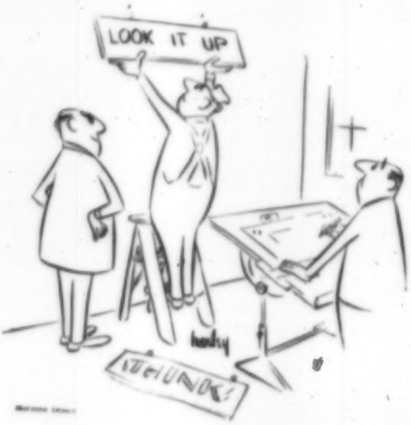
BOX 6, CENTERBROOK, CONNECTICUT

2CR54R

News Roundup

(Continued from Page 27)

ing size and shape with a minimum loss of operating time. Facilities are arranged so that rolls can be changed in one part of the mill while operations continue uninterrupted on other stands.



New Ceramic Coating For Nuclear Reactor Use

Because of the increasing demand for high-temperature protection of alloys in nuclear reactors, the National Bureau of Standards has developed a ceramic coating material of extremely low thermal neutron absorption properties. Investigation of over 200 ceramic mixtures resulted in a coating capable of withstanding temperatures in excess of 1000 C.

Ceramics or metal-ceramic combinations offer the only alternative to the use of bare metal for shields, moderators and fuel rods in atomic piles. Suitability of a ceramic coating for pile construction is determined by its neutron absorption coefficient. When placed in the path of a neutron beam, its absorption of neutrons must be low and should not exceed the absorption coefficient of the alloy to which it is applied.

Boron, a common element contained in ceramic coatings, has an unusually large neutron capture cross-section. As a result, materials investigated were relatively boron-free. Best results were obtained with a high-barium mixture combined with cerium and chromic oxide as the refractory addition. Coatings were applied to types 321 and 309 stainless steel. NBS also reports good results when the coating was applied to Inconel.

• • • SUN COOKSTOVES *are being developed as a possible household item for tropical areas by New York University's College of Engineering. Planned to be mass-produced for the average family in these underdeveloped areas, the stove is expected to raise the standard of living. At least it should clear the way for more appetizing meals, since it is reported that animal dung is often used for fuel in many of those areas.*

Centrifugally Cast Titanium Successful

First true centrifugal casting of titanium was announced recently. Developed as a result of metallurgical research at the Armour Research Foundation of Illinois Institute of Technology, the process is said to prevent contamination from furnace and mold materials.

Sponsorship of the project was by Wisconsin Centrifugal Foundry Inc. who also designed and supervised the casting equipment and techniques.

Previous attempts at casting titanium resulted in castings having rough surfaces because of the property of liquefied titanium to attack almost any other material. Titanium castings usually contained impurities because of absorbed gases from the furnace and mold materials.

While details of the new process have not yet been released, it was announced that castings weighing from 3.3 to 9 pounds have been produced.

Resistance to corrosion and a high strength-to-weight ratio make titanium castings highly desirable for many applications. Now that production bottlenecks appear closer to being eliminated, ARF metallurgists promise new uses for

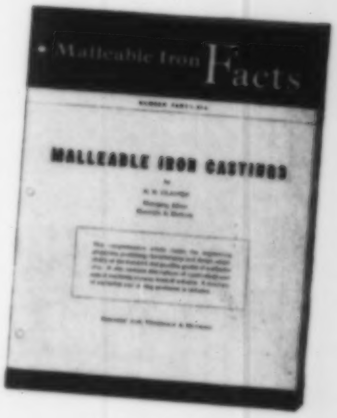
(*Continued on Page* 36)

...How about Malleable?

Versatile Castability Permits Wide Freedom of Design

The ability of malleable iron to be cast into intricate shapes and close to final form provides the design engineer with an extremely useful ferrous material. Complicated and expensive assemblies can often be combined into one easily machined, tough casting. Drilling and boring operations are often eliminated for further savings.

Whether you are designing new products or reviewing present production keep malleable in mind. Call a malleable foundry and go over your products with their engineers. They can give you information and suggestions that help you design better products that can be made at lower cost.



Free Design and Application Data to Help You Design with Malleable

This issue of Malleable Iron Facts contains valuable data on grades, design and application of malleable iron to aid the design engineer.

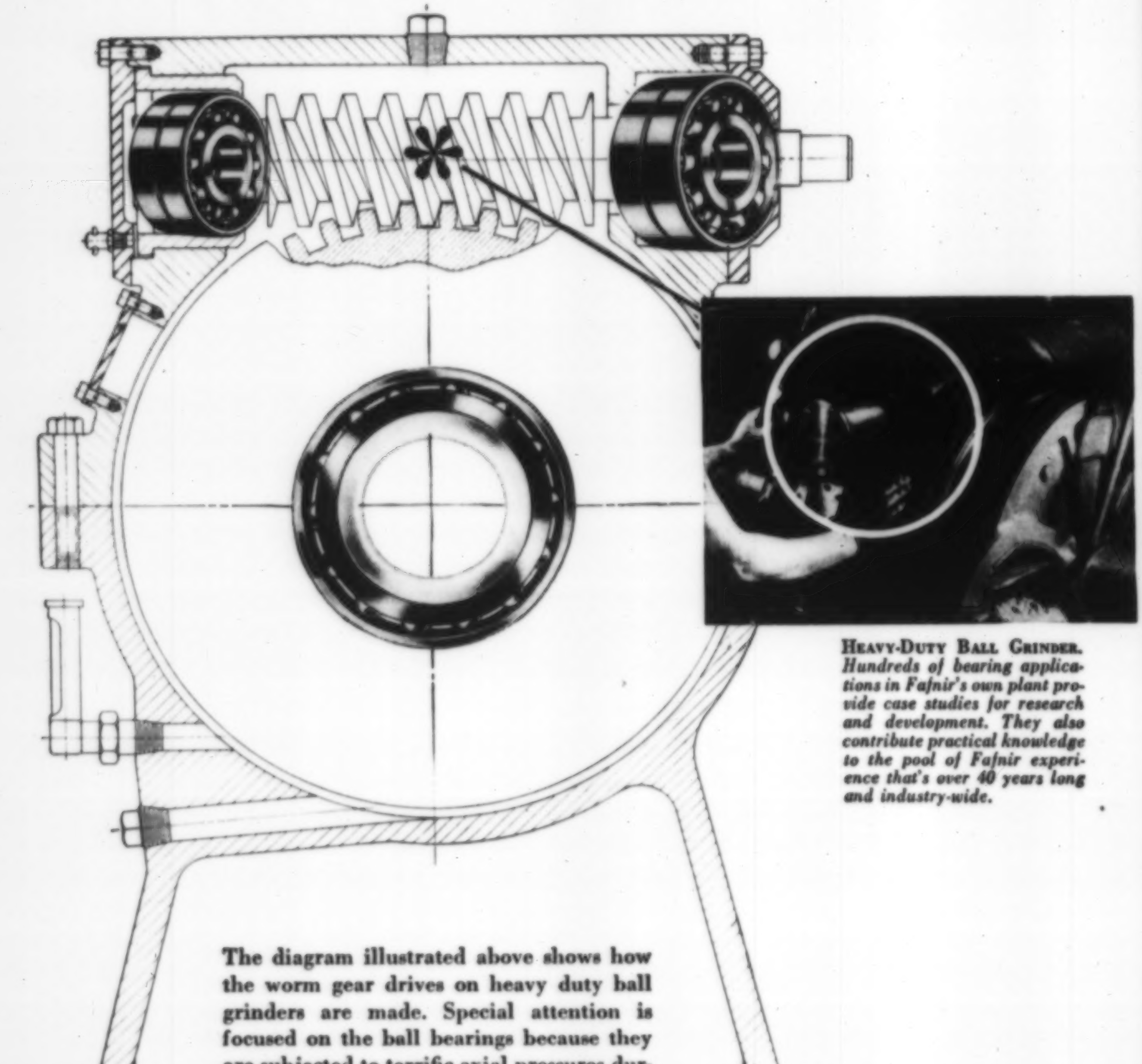
Ask your malleable castings supplier for copies or write to the Malleable Founders' Society

Malleable FOUNDERS' SOCIETY

1800 Union Commerce Building **Cleveland 14, Ohio**

More Turns For The Worm

on Fafnir Ball Bearings



Heavy-Duty Ball Grinder. *Hundreds of bearing applications in Fafnir's own plant provide case studies for research and development. They also contribute practical knowledge to the pool of Fafnir experience that's over 40 years long and industry-wide.*

The diagram illustrated above shows how the worm gear drives on heavy duty ball grinders are made. Special attention is focused on the ball bearings because they are subjected to terrific axial pressures during grinding operations when balls pass between grinding plates and grinding wheels.

The effectiveness of this bearing application is a matter of record. On the worm gear shaft illustrated, the duplex pairs of bearings have been in operation for 16 years without replacement . . . protecting the worm gear by rigidly locating its shaft and affording adequate carrying capacity for the combined radial and heavy thrust loads.

If you have similar equipment, maybe we can help extend its service life. The Fafnir Bearing Company, New Britain, Conn.

FAFNIR
BALL BEARINGS
MOST COMPLETE LINE IN AMERICA

It's worth it!

EVERY FRIDAY MORNING Holo-Krome's top production and management team literally "tear the place apart" to give H-K distributors Holo-Krome's famous Same-Day Service.* *But it's worth it!* For this same-day Holo-Krome service—*one shipment, one invoice, the same day we get the order*—saves our distributors plenty of time and money! *They* like it—their *customers* like it —and we like it. *And we guarantee to keep it that way!*

** 4 weeks or sooner on Specials*

THE HOLO-KROME SCREW CORP., HARTFORD, CONN., U. S. A.

HOLO-KROME
Completely Cold Forged
SOCKET SCREWS

Telesyn®
SYNCHROS
from FORD INSTRUMENT
for
extreme accuracy
in transmitting
signals

STANDARD TELESYN SYNCHROS
are available from Ford
Instrument in

Size 1 Size 3
Size 5 Size 23

for EARLY DELIVERY

A pioneer in the field of synchronous transmission, Ford Instrument produces synchros of proven precision accuracy.

- Available to meet Mil specs
- In sizes to meet a multitude of requirements
- For torque transmission and voltage indication

FREE a fully illustrated technical data bulletin gives characteristics and specifications. Please address Dept. MD.

43

FORD INSTRUMENT
COMPANY
Division of The Sperry Corporation
31-10 Thomson Ave.
Long Island City 1, N. Y.

Ford Instrument's standard lines

Rate Generators | Differentials | Servo Motors
Telesyn Receivers | Integrators | Telesyn Synchros

(*Continued from Page* 31)

titanium castings. Among these uses are sealing rings, bushings and fittings in areas where salt-water corrosion is a problem.

Push a Button To "Grease" Your Car

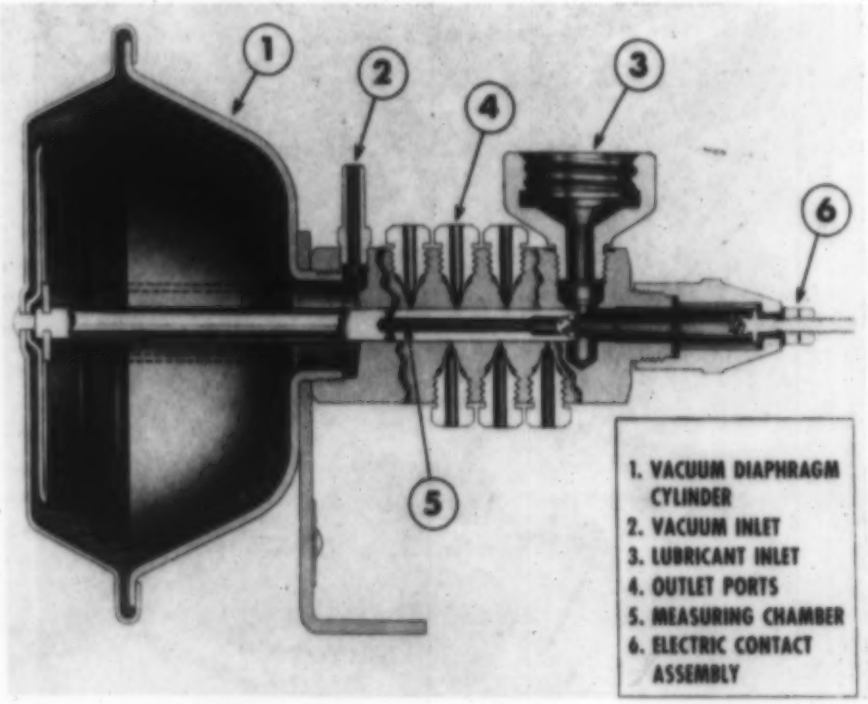
A new device available as optional equipment on some of the 1955 automobiles will lubricate 12 vital bearing points at one shot. Called the Multi-Luber, the unit is made by Lincoln Engineering Co.

Pushing a control button on the panel automatically actuates a vacuum system. In turn, a special compounded fluid grease is metered through 12 tubular nylon feed lines. Specially designed couplings fit over the regular grease fittings at the 12 bearing points.

Vacuum for the system is drawn from the intake manifold. Pressing the button admits vacuum to the injector pump. Motion of the vacuum diaphragm forces a plunger into the lubricant chamber, and lubricant under pressure passes into a measuring chamber in the plunger. As the dispensing grooves of the plunger become aligned with each part, a measured amount of lubricant is forced into the nylon tubes.

Specially designed adapters lock the nylon feed lines to a standard grease fitting

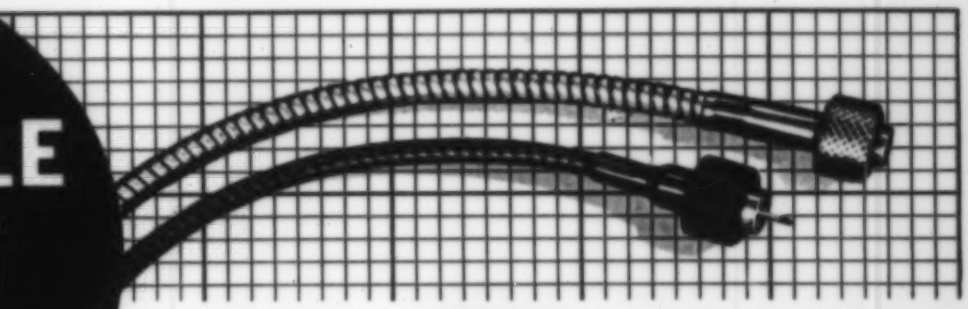
About 0.002-ounce of lubricant is forced into each bearing at each operation. At 70 F, about 10 inches of vacuum are required to



Heart of the Multi-Luber powered lubrication system for autos is this vacuum-operated injector pump which is located in the engine compartment. Six of the 12 outlet ports are shown which feed a metered amount of special fluid grease through nylon tubing to 12 critical bearing points

FLEXIBLE SHAFT

Fact and Fiction



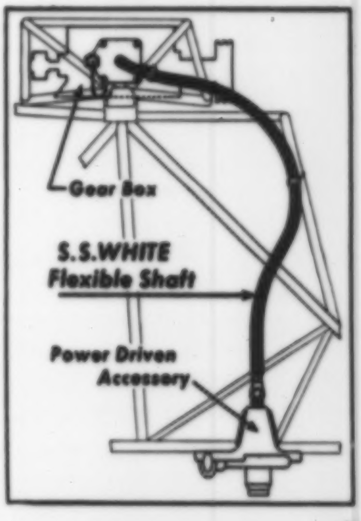
FACT

For transmitting power around turns, S.S.White Flexible Shafts simplify many design problems.

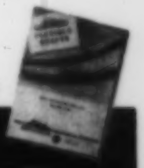
WHY? Because S.S.White flexible shafts are especially designed for use where rigid couplings are impractical. They do not require alignment, can be readily run around obstructions and are quickly and easily installed. Likewise, their adaptability to any design requirement gives you greater freedom in locating coupled parts to best advantage.

EXAMPLE — Power drive for an auxiliary pump

The specifications for this application called for mounting an auxiliary pump on the bottom of a helicopter fuselage. The closest power take-off to drive the pump was an accessory gear box located some distance away. An S.S.White flexible shaft, run around and over the intervening struts and frames made it possible to drive the pump *with a minimum of parts and with big savings in installation and assembly time.*



FLEXIBLE SHAFT FACTS FOR DESIGNERS



BULLETIN 5306 gives basic information and data about flexible shafts and tells how to select and apply them. Write for a free copy. Address Dept. 4.

F-2

THE S.S.White INDUSTRIAL DIVISION
DENTAL MFG. CO.
10 East 40th Street
NEW YORK 16, N. Y.

Western District Office • Times Building, Long Beach, California

FICTION Flexible Shafts are the same as steel springs

It's fiction because S.S.White flexible shafts are entirely different and in no way interchangeable with springs. S.S.White flexible shafts are specifically engineered for two basic functions – transmitting rotary power and remote control.

What's more – in design, in construction and in physical characteristics, as well as in performance – S.S.White power drive and remote control flexible shafts provide a range of qualities which are impossible to obtain in steel springs.

STACKPOLE

CARBON and GRAPHITE SPECIALTIES

Get this helpful booklet! In addition to details on Stackpole products, this 44-page Booklet 40A includes helpful engineering discussions on the physical and electrical properties of carbon and graphite. Copy sent free on letterhead request.

- GRAPHITE TUBE ANODES
- BATTERY CARBONS
- GROUND RODS
- NON-WELDING ELECTRICAL CONTACTS
- VOLTAGE REGULATOR DISCS (carbon piles)
- WATER HEATER and PASTEURIZATION ELECTRODES
- BEARINGS
- WELDING RODS
- WELDING PLATES and PASTE
- RESISTANCE WELDING and BRAZING TIPS
- CHEMICAL CARBON and GRAPHITE (Plain or Treated)
- CARBON RODS FOR SALT BATH RECTIFICATION
- TROLLEY SHOES
- SEAL RINGS
- FRICTION SEGMENTS
- CLUTCH RINGS
- BRAZING FURNACE BOATS
- ELECTRIC FURNACE HEATING ELEMENTS
- MOLDS and DIES
- CONTINUOUS CASTING DIES

STACKPOLE CARBON COMPANY
St. Marys, Pa.

EVERYTHING IN CARBON BUT DIAMONDS

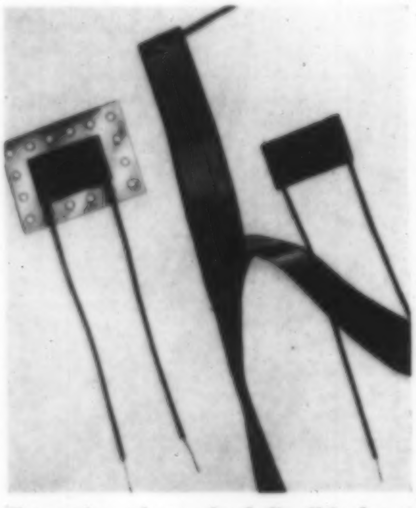
operate the unit. Nylon tubing used for feed lines and made by Polymer Corp. of Pennsylvania is 1/16-inch inside diameter and tests at approximately 2500 psi burst pressure.

One advantage claimed for the device is its ability to function if a feeder line is broken. All other bearings will continue to receive their prescribed amount of the fluid grease. Damaged lines are said to be easily repaired with a special coupling union.

Generally, the Multi-Luber should be operated once a day or every 50 miles. It is said to be capable of operating about 290 cycles on one filling. At normal temperatures, it takes from 3 to 5 seconds for one operation. A green light on the panel indicates when the cycle is complete.

Heaters Get In Out-of-the-Way Places

Flexible electric heating elements made in standard shapes and sizes can be wound around irregular surfaces to provide uniform heating. Using silicone rubber and glass fiber insulation, the units are said to be able to perform continuously at temperatures



Examples of standard flexible heating strips made by Electro-Flex Heat Inc., to heat irregular shapes or out-of-the-way places in excess of 450 F.

Made by Electro-Flex Heat Inc., the elements range in thickness from 0.050 to 0.100-inch. They were designed to supply heat in many places where other types of heating elements would be unsuitable. Generally, they are expected to find application in curing thermosetting resins and maintaining temperatures of mechanical and electrical equipment. Pressures over 100 psi are said not to affect operation of the elements. Light weight of these flexible blankets and strips is expected to make them adaptable to a variety of uses.

Titanium Rivets Have New Design Possibilities

Recent tests of titanium rivets have brought to light interesting possibilities for their application in aircraft structures.

A series of tests by Olympic Screw and Rivet Corp. points up the fact that titanium may have a distinct field of application along with other materials such as steel, aluminum and Monel in the aircraft industry.

Primarily, the favorable strength-weight advantage of titanium makes the use of titanium fasteners attractive. High strength, high temperature and good corrosion-resistant characteristics can all be met by titanium. Problem, though, is the successful installation and use of titanium as rivets.

To date, Olympic reports, encouraging results of tests have led to the conclusion that titanium riveted fasteners are feasible. It was found that acceptable upset heads can be formed cold, either by bucking the head or the tail of the rivet. Shear strength is about 58,000 psi. Experiments also showed that workable blind fasteners are feasible.

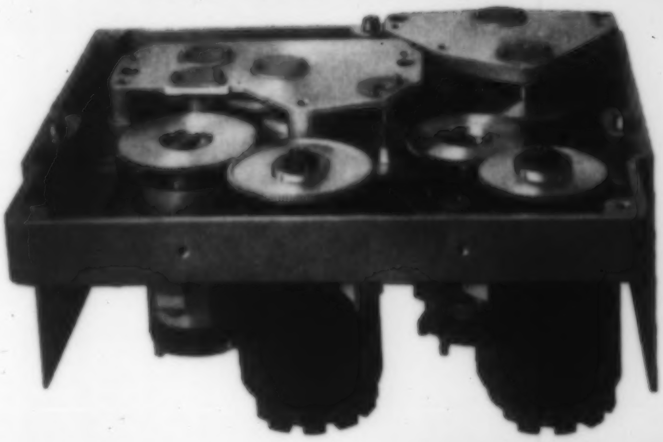
AGMA Index shows volume for the gearing industry to be increased by 12.7 per cent in October, 1954, as compared with September, 1954.

How Grant PRECISION GEARS solved both COST and QUALITY CONTROL PROBLEMS

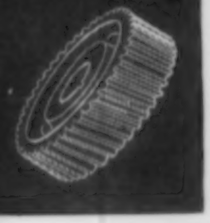
THE PROBLEM:

Sig-Trans Inc., designers and manufacturers of Synchro-Signal Amplifiers for the U. S. Navy, require precision gear trains in large quantities. It is imperative that each gear be uniformly accurate to produce finished gear trains which are assigned the delicate task of aligning synchro-mechanisms for coordinating all Gyro-Compasses throughout Navy vessels.

Production costs increased as chassis assembly was halted time and again because gears could not be quickly and uniformly matched.



THE SOLUTION:



Sig-Trans turned to GRANT. Here they found the experience and skill necessary to mass produce gear trains containing 19 different types, so uniform that chassis assembly was completed rapidly and economically. Gear rejection dropped to zero. Remarkable quality control in the face of such a precision application.

For information on how GRANT GEARS will help you solve both cost and quality control problems in the design and production of electronic equipment, write, wire or call . . .

GRANT GEAR INC. WORKS

172 West Second Street Boston 27, Mass.

Founded in 1877 by George B. Grant the Pioneer Gear Man

HOW TO PICK
THE RIGHT PUMP
FOR THE JOB

TUTHILL ***Simplifies Pump Selection for PRODUCT DESIGNERS***

To make it easy for product designers to select the right oil pump for the job, Tuthill offers new catalog data covering pump models to meet the specific pumping purposes outlined below. Each catalog features an individual pump guide so you can select the exact pump to fit your need. Check the following services and ask for the Tuthill catalogs you wish by Catalog number indicated.

For PRESSURE LUBRICATION

		Catalog No.
Model L	⅓ to 6 g.p.m. up to 200 p.s.i.	101
Model C	2 to 200 g.p.m. up to 100 p.s.i.	102
Model R	¾ to 200 g.p.m. up to 100 p.s.i.	105
Models S & SA	⅓ to 200 g.p.m. up to 200 p.s.i.	106

For HYDRAULIC SERVICE

		Catalog No.
Model L	⅓ to 6 g.p.m. up to 600 p.s.i.	101
Model CK	5 to 200 g.p.m. up to 400 p.s.i.	103
Model R	¾ to 200 g.p.m. up to 400 p.s.i.	105
Models S & SA	⅓ to 200 g.p.m. up to 200 p.s.i.	106

For COOLANT SERVICE

		Catalog No.
Model C	2 to 200 g.p.m. up to 100 p.s.i.	102
Model CK	100 to 200 g.p.m. up to 200 p.s.i.	103
Model M	2 to 50 g.p.m. up to 15 p.s.i.	104
Model R	2 to 200 g.p.m. up to 100 p.s.i.	105
Models S & SA	2 to 200 g.p.m. up to 200 p.s.i.	106

For TRANSFER AND CIRCULATING

		Catalog No.
Model L	⅓ to 6 g.p.m. up to 200 p.s.i.	101
Model C	2 to 200 g.p.m. up to 100 p.s.i.	102
Model CK	100 to 200 g.p.m. up to 200 p.s.i.	103
Model R	2 to 200 g.p.m. up to 100 p.s.i.	105
Models S & SA	2 to 200 g.p.m. up to 100 p.s.i.	106

For BURNING OILS

		Catalog No.
Model L	⅓ to 6 g.p.m. up to 200 p.s.i.	101
Model C	2 to 50 g.p.m. up to 100 p.s.i.	102
Type SU	2 to 50 g.p.m. up to 300 p.s.i.	107

For BUILT-IN APPLICATIONS

All standard Tuthill Pump models are available in stripped form for building into the design of your equipment. Ask for Catalog No. 106.

TUTHILL PUMP COMPANY
Dependable Rotary Pumps since 1927
939 East 95th Street, Chicago 19, Illinois
Canadian Affiliate: Ingersoll Machine & Tool Co., Ltd.
Ingersoll, Ontario, Canada

News Roundup

The index figure for October, 1954, is computed to be 152.3. AGMA index figures are computed using the 1947 to 1949 period as a base of 100.

MINIATURE POT with high accuracy is the result of a combination of several new design features. Measuring ⅞-inch in diameter, this potentiometer, developed by Gyromechanisms Inc., is reported to have an accuracy of ±0.1 per cent for linear functions. Platinum to give low contact resistance, low torque, low noise and long life, along with a precision method of winding, combined to result in this lightweight unit

• • • ELECTRONIC CAKE BAKING *was demonstrated recently by Magnecord Inc. The process consists of recording signals on magnetic tape that correspond to cake mixing operations. Connecting the output of a tape playback to the various machines with the proper circuitry automatically mixes and bakes the cake. Baking a cake may some day be as simple as picking up the right tape at the local supermarket. If it doesn't taste right, housewives can always blame it on a burned out tube.*

Radio Corporation of America has announced the establishment of a separate Semi-Conductor Operations Dept. All of RCA's transistor engineering and manufacturing along with development and manufacturing of other semiconductor devices will be handled by the new department.

New Basis Revealed for Selecting Bearing Metals

Tests of virtually all types of bearing metals have resulted in a new theory of what makes good sliding surfaces and what doesn't. In a recent report, three General Motors Research Laboratories engineers, described what they believe is a new basis for selecting bearing metals.

After testing a wide range of bearing metals rubbing on steel journals, the GM engineers reported that results indicate bearing metals fall into two categories. These are: (1) the insoluble B-subgroup metals in the periodic table and (2) the metals that form intermetallic compounds with iron.

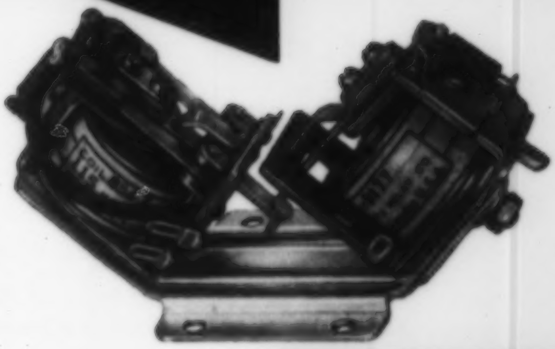
It was found that if sliding metals are soluble, they will seize, score or weld. If they are insoluble, they will tend to form welded junctions on a microscopic scale. Whether or not they will make a good bearing depends upon the character of these junctions.

If the junctions break cleanly, with little or no tendency to propagate, the metal is good. These metals have been found to be the insoluble B-subgroup such as silver, cadmium, indium, thallium, lead and bismuth. If the microscopic junctions tend to smear and propagate other junctions, the metal is unsatisfactory for bearings. This is characteristic of the non B-subgroup metals.

Those metals that form intermetallic compounds with iron make up the other class of good bearing metals. Such compounds are brittle and easily broken. Damage is confined to the surface and damage in depth is minimized. Some of these metals are tin, antimony, selenium, tellurium and germanium.

Price reduction of ductile titanium metal sponge has been an-

NEW *Leach*
ANGLE MOUNTED
LATCHING RELAYS
For Unlimited Control Applications . . .



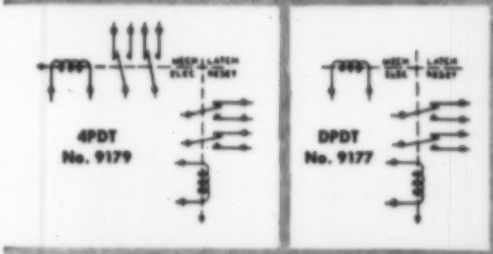
Designed to take it . . .

DIMENSIONS

Resistant to vibration and shock, these new LEACH commercial and industrial relays incorporate unique principal of angle mounting for coil mechanism. These compact and rugged relays are designed to give efficient, dependable performance *mounted in any position*—vertical, diagonal, etc.

NEW WEDGE ACTION . . . Utilizing latch faces with a slight radius plus end to end operation of latch mechanism, *positive latching* is assured regardless of wear or play in armature hinge joints. Standard coils are varnish impregnated and surfaces of frame, base, bracket, etc., are electro-plated.

SCHEMATIC



CHARACTERISTICS
CONTACTS: DPDT or 4PDT.
CONTACT RATING:
8 amps. @ 115 VAC non-inductive or 8 amps. @ 29 VDC resistive load.
COIL: Continuous or intermittent duty with resistance to 10,000 ohms. Maximum voltage 120 VAC 60 cycle or 120 VDC. Special series coils available.
WEIGHT: .38 lb.

Unusual opportunities in research, design and development for engineers!
Submit resume of qualifications and experience.
FOR BETTER CONTROLS THROUGH BETTER RELAYS—*Specify* LEACH
Specialists in Electronics and Electro-Mechanics

LEACH RELAY CO.

5915 AVALON BOULEVARD • LOS ANGELES 3, CALIFORNIA.
Representatives in Principal Cities of U.S. and Canada

SAVING MONEY
for TAXPAYERS in CONNECTICUT

or NUT GROWERS in CALIFORNIA

with
HYDRECO
FLUID MOTORS

You find the answers to so many problems in the wide experience of HYDRECO engineers . . . especially where a function involves rotary motion. Powering the sweeper or the snow blower on municipal equipment, driving conveyor belts on trenchers, or shaking walnuts out of the trees at harvest time . . . these are but a few of hundreds of money-saving operations HYDRECO Fluid Motors are called upon to perform.

HYDRECO Fluid Motors, with their high starting torque, instant reversibility, and capacity for handling rugged and seemingly impossible assignments, are the natural choice of design engineers. HYDRECO dependability stems from the fundamentally sound "Pressure-Balanced" design, unmatched craftsmanship and the "know-how" of thousands of outstanding hydraulic applications.

These famous Gear Type Motors operate with pressures up to 1500 psi. Available in flange or foot-mounted models, in a complete range of sizes to 52 hp. They feature the exclusive HYDRECO Four Bolt design which places greatest strength in the area of greatest pressure.

Write for full information on HYDRECO Hydraulic Pumps, Motors, Valves and Cylinders today!

HYDRECO DIVISION
THE NEW YORK AIR BRAKE COMPANY
1106 EAST 222nd STREET • CLEVELAND 17 • OHIO

nounced by Du Pont. Grade A-1 ductile titanium metal sponge containing a maximum of 0.3 per cent iron is $4.50 a pound, a reduction of 22 cents. Grade A-2, with a top iron content of 0.5 per cent, $4.00 a pound, a reduction of 46 cents.

"Forget your slide rule again, Scrom?"

Engineer Will Receive Honor Medal

Harry A. Winne, retired vice president of General Electric Co., will be presented the 1954 John Fritz Medal by the four founding engineering societies. Mr. Winne has been prominent in the field of nuclear energy since World War II and supervised GE's atomic energy projects. He is the 51st winner of the medal, which was established in 1902, and will be honored "for service to his country in war and peace through distinguished leadership in the electrical industry."

The honor medal will be presented at the AIEE winter meeting in New York Jan. 31 to Feb. 4, 1955.

U. S. aluminum industry chalked up another production record in the third quarter of 1954. Although September primary production of 240,644,643 pounds was slightly lower than August, the total third quarter production of 743,581,012 pounds represents a new all-time high and breaks the record set this year in the second quarter, when 732,660,294 pounds were produced.

All-Aluminum Truck Designed to Get Ideas

Weighing about 3 tons less than a conventional truck of the same capacity, an all-aluminum truck has been designed by Chrysler Corp. for the U. S. Army. A fuel injection system, hydraulic disk brakes and ball-joint suspension are among the "idea" features of the truck.

Designed to be used for airborne operations, the truck is a cab-ahead-of engine model with 6-wheel drive and weighs 9000 pounds. Body, wheels and axles are all aluminum. An aluminum cab is open on top with a plastic cover. Instead of folding flat on the hood, the windshield slides up and down.

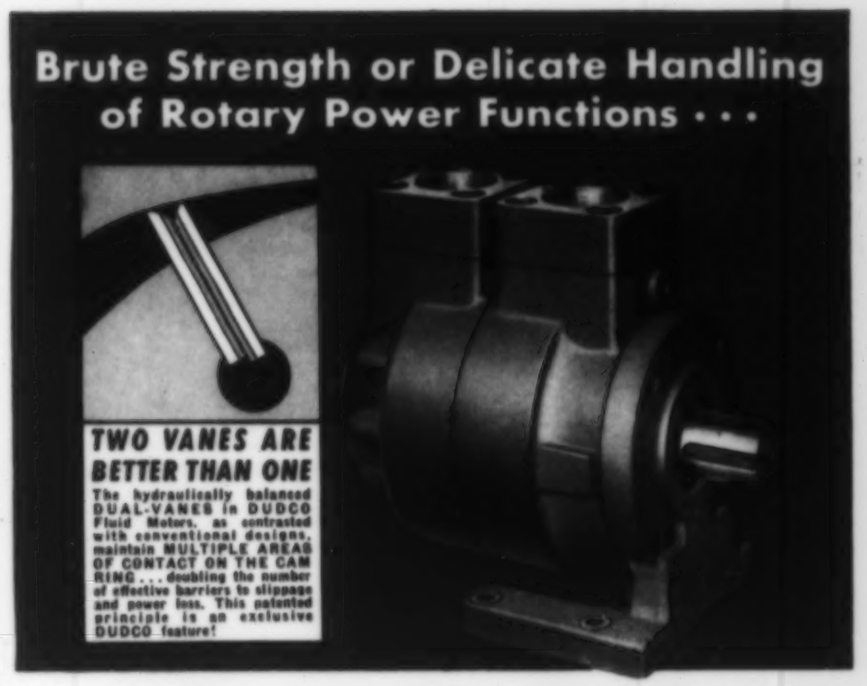
Powered by a waterproof, 6-cylinder, 200-hp air-cooled engine, the vehicle is capable of speeds over 60 mph. A fuel injection system is used instead of a carburetor, which eliminates loss of engine speed on hills. An automatic gear shift is said to make the truck nearly impossible to stall.

Designated the T55 by Chrysler, the truck is said to be the first military vehicle equipped with ball-joint suspension. Front and rear axles are interchangeable and each wheel has hydraulic disk brakes operated by an air-assisted hydraulic system.

Performance-wise, the truck is said to handle and ride like a passenger car on the road. Off the road, it is said to compare favorably with track-laying vehicles.

New research and development center has been opened in Denver by Micro Switch, a division of Minneapolis-Honeywell Regulator Co. Its establishment is to be a part of a research program devoted to improving materials used in switches and developing new principles and methods of switch operation.

Brute Strength or Delicate Handling of Rotary Power Functions . . .



TWO VANES ARE BETTER THAN ONE

The hydraulically balanced DUAL-VANES in DUDCO Fluid Motors, as contrasted with conventional designs, maintain MULTIPLE AREAS OF CONTACT ON THE CAM RING . . . doubling the number of effective barriers to slippage and power loss. This patented principle is an exclusive DUDCO feature!

DUDCO
FLUID MOTORS

Compact and sturdy, DUDCO DUAL-VANE Fluid Motors operate quietly and smoothly under the most strenuous conditions. They're built to "take it" . . . frequent reversals, rapid accelerations or stalling under load. With DUDCO you get the big advantage of 2000 psi operation at a cost comparable with that of lower pressure equipment.

DUDCO is a big, exciting story for every hydraulics engineer because . . . power losses are minimized and operating efficiency is higher . . . starting torques are high . . . operation is smooth, quiet and exceptionally free from wear or maintenance problems.

On Conveyor systems for agricultural, food processing, mining and other industries, DUDCO DUAL-VANE Fluid Motors provide the extras in performance that save time, money and labor. Operating the winches on a giant tank retriever and other large mobile equipment calls for high starting torque and the dependable power of DUDCO DUAL-VANE MOTORS.

Write for Bulletin DM-301 fully describing DUDCO DUAL-VANE Fluid Motors today!

DUDCO DIVISION
THE NEW YORK AIR BRAKE COMPANY
1706 EAST NINE MILE ROAD • HAZEL PARK • MICH.

NOW--LOOK TO CHIEF SANDUSKY FOR FERROUS TOO!

★ CHIEF ★ SANDUSKY

FERROUS AND NON-FERROUS CENTRIFUGALLY CAST ROLLS, SLEEVES, LINERS, TUBES, CHUTES, RETORTS, BUSHINGS, BEARINGS, RINGS, ETC.

With the recent installation of high-frequency induction melting furnaces, Chief Sandusky now supplies industry with a diversified line of both ferrous and non-ferrous cylindrical castings. In addition to the convenience of single-source supply, we provide sound technical assistance from both the field and greatly expanded laboratory facilities.

With a skill born of 40 years' experience, time tested in hundreds of plants, you can call on our experienced technicians with confidence. They're ready to help you with manufacturing special castings to specification or working with your staff in developing unusual types to solve new problems.

Look to Chief Sandusky as a continuing dependable source of both ferrous and non-ferrous custom quality centrifugal castings.

C. M. LOVSTED & CO., SEATTLE, WASH. • TYNE BROS., BIRMINGHAM, ALA. • CORDES BROS., SAN FRANCISCO AND LONG BEACH, CALIF.

SANDUSKY
FOUNDRY and MACHINE CO.

615 W. Market Street
Sandusky, Ohio

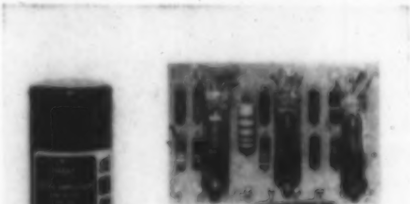
Heavy Metals Gulped Easily by This New Hose

Chunks of iron ore and coal weighing up to 10 lb are gulped down easily by a newly developed rubber hose. Used in the mining industry, the hose was developed by B. F. Goodrich to convey chunks of coal from the mine to the processing plant. Pieces up to 8 inches long are carried along inside the hose by water at a pressure up to 250 psi.

Secret of the hose is reported to be a special rubber compound called Armorite. Goodrich claims Armorite lasts 20 times as long as steel in many applications. Spiral wire reinforces the hose inside to prevent kinking, crushing and collapsing.

Advantage of the new hose is its ability to negotiate corners. Abrasive materials carried in ordinary pipe at high velocities often cause wear at those points. Short lengths of the new tubing can be bent around corners at these critical points. The pipe can also be rotated to distribute the wear.

The new hose is reported available in sizes from 1 to 14 inches in di-



ROLLED CIRCUITS are etched on impregnated Teflon. These three-tube circuits may be amplifiers, computer circuits, pulse circuits or oscillators. After printing, they are rolled and cased as shown. They may be hermetically sealed for use with guided missiles ameter. It is constructed for working pressures from 50 to 250 psi.

SIMPLIFIED DESIGN of these lathe controls is said to eliminate possibility for human error, according to Monarch Machine Tool Co. All the operator does is set two dials, one for surface cutting speed, and one for the diameter of the piece to be turned. Gears are shifted automatically to give the correct spindle speed

New Metal Coatings Fuse at Low Temperatures

A newly developed silicate coating that permanently bonds to metal at low temperatures was recently announced by Allied Porcenell Inc. The new coatings feature resistance to corrosion, are not subject to organic changes, and have permanent color not affected by sunlight.

Developed by Vitreco Inc. and Youngstown Sheet & Tube Co., the coatings are claimed to be a major new finish. They are said to provide a decorative, permanent finish at costs comparable to existing metal-finishing systems.

Outstanding advantage of the new Porcenells, according to the company, is its ability to be bonded to metal at relatively low temperatures. Curing temperature is 900 F. Warpage of the base metal is

(Continued on Page 48)

BUILD YOUR BUSINESS ALONG THESE LINES

with BIJUR Automatic Lubrication

By incorporating the Bijur System into your designs, you can offer substantial operating economies which progressive users now demand. For example, in the metalworking field 75% of machinery users prefer "built-in" automatic lubrication on the machines they buy.

Costly hand lubrication is eliminated.

Production time is saved because machines are oiled while in operation.

Bijur Automatic Lubrication is the best friend a bearing ever had. Every bearing is automatically fed a metered shot of oil at predetermined intervals.

Inaccessible bearings that require regular lubrication are never neglected.

There can be no problem of work spoilage or bearing headaches caused by over lubrication.

Leading machine builders have standardized on Bijur for a quarter of a century. Bijur puts the accent on engineering design – to satisfy the specific requirements of your machines.

Our engineers can show you how to build increased dependability into your machines, whether they are in production or still on the board.

G-4

Write for literature and engineering data.

1370

BIJUR
LUBRICATING CORPORATION
Rochelle Park, New Jersey
Pioneers in Automatic Lubrication

Mechanical

Where moderate speed range is required and where machine may be stopped to make speed changes. Horsepower range—1½ to 300. Speed adjustment range—9 to 28 percent. Two *Vari-Pitch* sheaves used together **double range of adjustment.**

Combination starter

Squirrel-cage motor

***Vari-Pitch* stationary control drive**

Mechanical

Where infrequent change of speed in low horsepower drives is required and machine may be stopped for speed adjustment. Especially suitable for fan drives, stokers, small pumps and tools. Horsepower range—fractional to 4 hp. Speed adjustment range—18 to 50 percent. Use of two adjustable sheaves doubles speed adjustment range.

Across-the-line starter

Squirrel-cage motor

***Texrope* adjustable drive**

EIGHT WAYS TO GET VARIABLE SPEED

Electrical

Where stepped speed control is satisfactory. Available with stepless control in larger sizes by using liquid rheostat. Speed is varied by means of control on secondary windings of motor. Horsepower range—5 hp and up. Speed adjustment range—50 percent of synchronous speed to full load speed.

Wound-rotor motor control

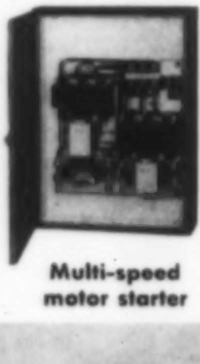
Wound-rotor motor

***Texrope* V-belt drive**

Electrical

Where a few definite speeds are required. Up to four speeds available from one motor. Motor is built on standard squirrel-cage frame with special windings and control. Furnished for variable torque, constant torque and constant horsepower. Horsepower range—½ hp up.

Texrope and Vari-Pitch are Allis-Chalmers trademarks.


Multi-speed motor starter

Multi-speed squirrel-cage motor

***Texrope* V-belt drive**

Write for Engineering Literature

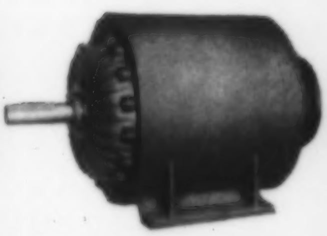
A-C ALLIS-CHALMERS

ALLIS-

Mechanical

Where speed must be changed while machine is in motion. Particularly good for machines requiring fine adjustment while operating. Double range of adjustment may be obtained by using two *Vari-Pitch* sheaves. Horsepower range—1½ to 600. Speed adjustment range—9 to 28 percent with one *Vari-Pitch* sheave.

Reduced voltage starter



Squirrel-cage motor

***Vari-Pitch* motion control drive**

Mechanical

Where very wide range speed control is required or where enclosed unit is desired. May be manually or remotely controlled. Motor may be mounted on speed changer housing for compact installation. Horsepower range—1½ to 75. Speed adjustment range—3¾ to 1.

Across-the-line starter

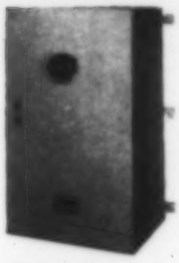
Squirrel-cage motor

***Vari-Pitch* speed changer**

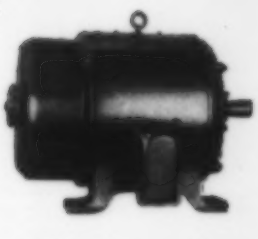
COMPLETE DRIVES
from One Reliable Source

Electrical

Where great versatility is required. Speed may be varied by various types of control, either stepped or stepless. For both constant and variable torque loads. Horsepower range—½ hp up. Speed adjustment range—zero to maximum speed. Maximum speed in smaller sizes, 3500 rpm.



Direct current control



Direct current motor

***Texrope* V-belt drive**

Combination

Where extremely wide range is required, a combination drive adds the speed control range of the motor to that of the *Vari-Pitch* drive. Hundreds of combinations of any of the above units can be worked out to fit the requirements of a particular design.

Wound-rotor motor control

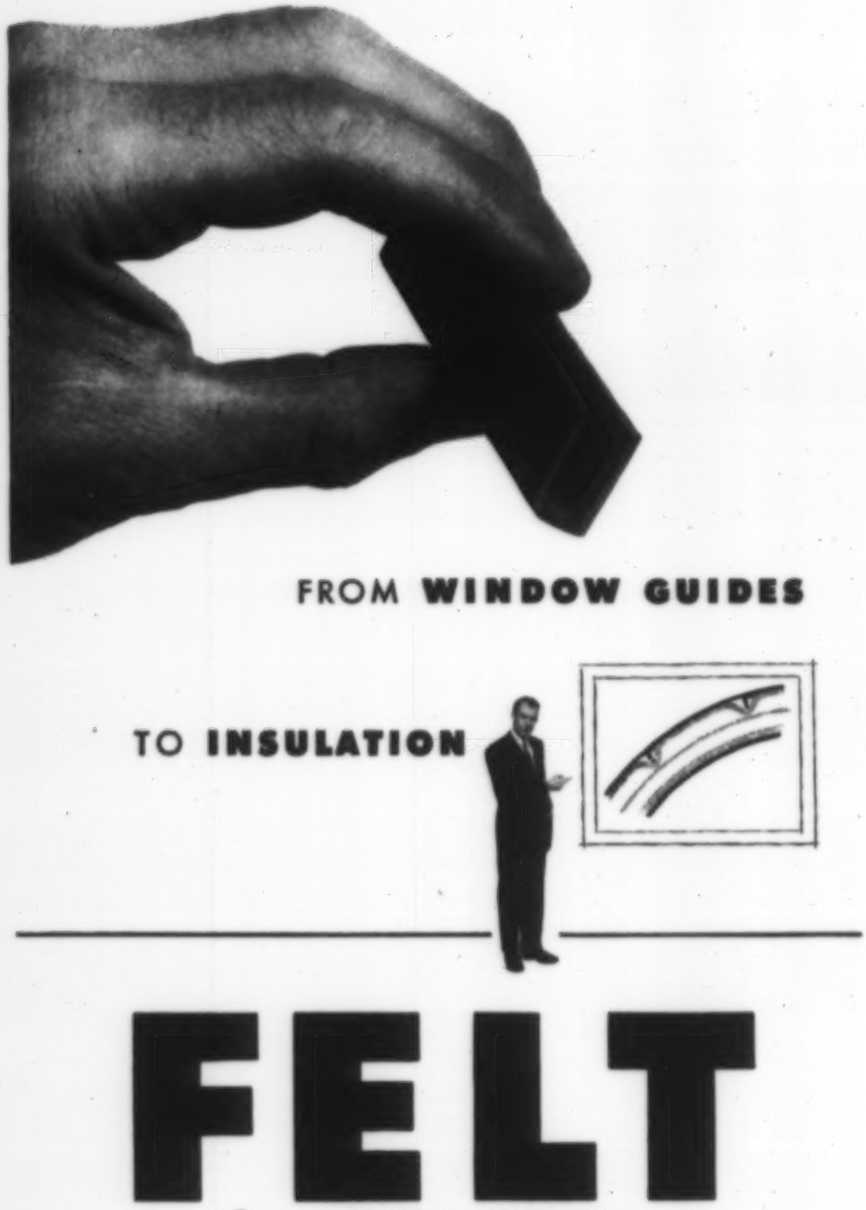
Wound-rotor motor

***Vari-Pitch* motion control drive**

A4523

CHALMERS

Milwaukee 1, Wisconsin



FROM **WINDOW GUIDES**

TO **INSULATION**

FELT

by FELTERS

DOES THE JOB RIGHT

For a good slip-fit without rattling or looseness, Felters Felt is an ideal design material. To insulate against heat or cold, there are grades of Felters Felt to solve many knotty problems.

If you would like information about felt's versatility in solving design problems, write to Felters. Our 16-page "Felt Design Book" describes many interesting problems that have been successfully solved by Felters Felt. Write for your free copy.
THE FELTERS CO., 218 South St., Boston 11, Mass.

FELTERS S.A.E. FELTS F-10, F-11 & F-13 are often used for oil or grease retention where the felt is compressed or confined in an assembly. Where operating conditions are not too severe, these grades are also used to make dust shields.

These are 3 of many grades of Felters Felt produced for specific applications.

FELTERS FELT

... by the roll ... by the yard
... or cut exactly as you want it

(*Continued from Page 45*)

practically eliminated and any gage metal may be used.

Special steels are not required. Porcenells are said to be easily applied to cast, wrought or malleable iron as well as carbon steels. They can be applied in a single coat in a variety of colors, including pastels. Textures may range from full matte to a high gloss.

For maximum corrosion resistance, two coats are recommended. Total coating thickness is said not to exceed 0.005-inch. Coated pieces may be cut, punched and drilled with little chipback.

Coatings provide full coverage. Square corners are completely covered, thus eliminating the necessity for special designs.

Porcenells expect to find usefulness in the architectural field for decorative use as well as corrosion protection. The coatings may be used as a corrosion-proof base for paint. Except for high-fire porcelain enamel, Porcenell coatings are claimed to have the highest scratch hardness and abrasion resistance of any commercial ferrous metal coating.

"Well, I've got the sixth revision done. It's about time for the seventh to come through."

Doelcam Corp. has been acquired by Minneapolis-Honeywell Regulator Co., it was announced recently. Doelcam manufactures precision instrument and control equipment for aircraft and industry. The acquisition is part of Honeywell's planned program of diversification, according to company officials.

PLASTIC MODELS for wind tunnel tests are proving an inexpensive substitute for models machined from steel. This jet-engine nacelle model, developed by Martin Aircraft, is molded with over 50 tiny pressure-measuring tubes embedded in the plastic

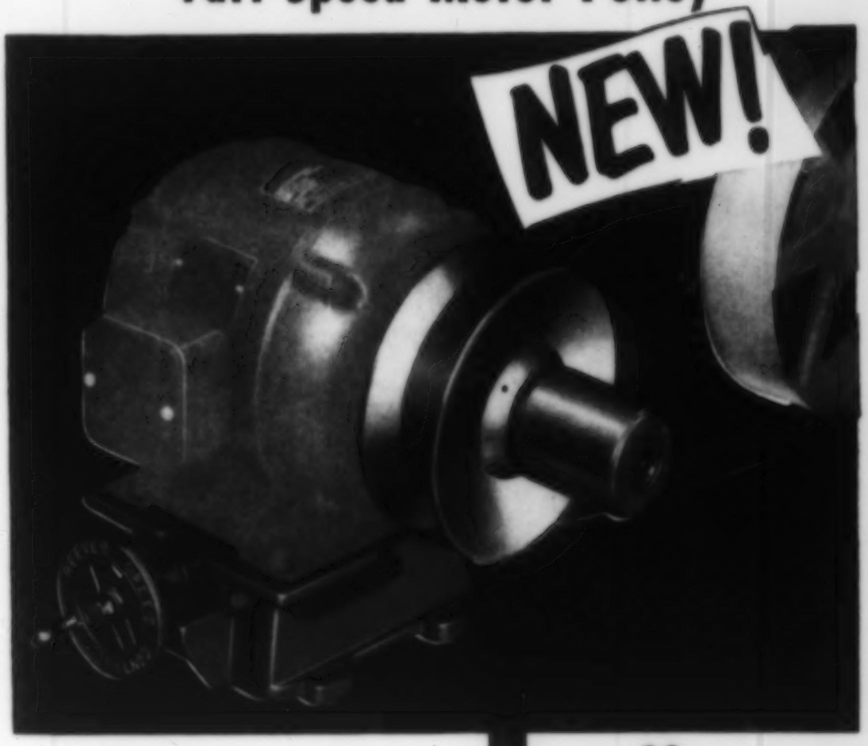
University of California, Los Angeles, is offering its first Engineering and Management Course next January 31 through February 11, 1955. This two-week course, a cooperative effort of the College of Engineering and School of Business Administration, will offer training in a full range of subjects from elementary concepts of management and motion-study to advanced concepts of linear programming and electronic data processing.

Meetings

AND EXPOSITIONS

Jan. 19-21—
Society of Plastics Engineers. Annual national technical conference to be held at the Chalfonte-

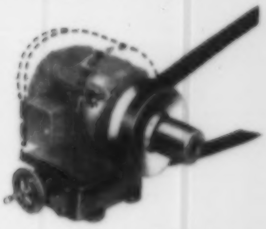
REEVES
Vari-Speed Motor Pulley



Smaller Units!
More HP!

Completely new redesigned line from ½ to 15 HP!

"spiral-groove" lubrication


For new or old NEMA Motors

CHECK ALL THESE NEW REEVES FEATURES

1 New, smaller disc assemblies are engineered for new NEMA Motors, yet usable with old.

2 New spiral-groove lubrication assures complete lubrication for years of rust-free, trouble-free service.

3 One-point lubrication. Unit can be lubricated when stopped, or *while in operation.*

4 Superior base construction provides greater rigidity and strength, reduces vibration and noise.

REEVES PULLEY COMPANY • COLUMBUS, INDIANA

Write for complete details and new bulletin today!
Specify Dept. H8b-V545.

Here's the NEW

2½ HP

ANGLgear
TRADE MARK

Designers and engineers have been asking for this big right-angle drive. It's rated at 2½ hp at 1200 rpm, will transmit a maximum torque of 2500 lb. in.

This right-angle giant, Model 340, is a logical development of Airborne's smaller ANGLgear models. It has the same features that have made ANGLgear the most popular power takeoff in industry. ANGLgears are sold only through your local distributor. See our literature in the product design section of Sweet's Catalog.

AIRBORNE
Accessories Corporation
HILLSIDE 5, NEW JERSEY

Haddon Hall Hotel, Atlantic City, N. J. Additional information may be obtained from society headquarters, 513 Security Bank Bldg., Athens, O.

Jan. 21—

Malleable Founders' Society. General meeting to be held at Hotel Cleveland, Cleveland, O. Additional information may be obtained from society headquarters, 1800 Union Commerce Bldg., Cleveland, O.

Jan. 24-27—

Plant Maintenance & Engineering Conference to be held at the International Amphitheatre, Chicago, Ill. Additional information may be obtained from the exposition management, Clapp & Poliak Inc., 341 Madison Ave., New York 17, N. Y.

Jan. 24-28—

Institute of the Aeronautical Sciences. Twenty-third annual meeting to be held at Hotel Astor, New York, N.Y. R. R. Dexter, 2 East 64th St., New York 21, N. Y., is secretary.

Jan. 24-28—

Twelfth International Heating and Ventilating Exposition to be held at the Commercial Museum and Convention Hall in Philadelphia, Pa. E. K. Stevens, 480 Lexington Ave., New York 17, N. Y., is manager.

Jan. 31-Feb. 4—

American Institute of Electrical Engineers. Winter general meeting to be held at Hotel Statler, New York, N. Y. Nelson S. Hibshman, 33 West 39th St., New York 18, N. Y., is secretary.

Feb. 8-10—

Society of the Plastics Industry. Tenth annual reinforced plastics division conference to be held at Hotel Statler, Los Angeles, Calif. Additional information may be obtained from society headquarters, 67 West 44th St., New York 36, N. Y.

Feb. 14-18—

American Institute of Mining & Metallurgical Engineers. Annual meeting to be held at the Conrad Hilton Hotel, Chicago, Ill. Additional information may be obtained from society headquarters, 29 West 39th St., New York 18, N. Y.

Feb. 18-19—

National Society of Professional Engineers. Annual spring meeting to be held at Hotel Charlotte, Charlotte, N. C. Additional information may be obtained from society headquarters, 1121 15th St., N. W., Washington 5, D. C.

Mar. 1-3—

Joint Western Computer Conference and Exhibit to be held at the Statler Hotel, Los Angeles, Calif. Sponsored by IRE, AIEE, and Association for Computing Machinery. William Gunning, International Telemetering Corp., 2000 Stoner Ave., Los Angeles 25, Calif., is conference secretary.

Mar. 7-11—

National Association of Corrosion Engineers. Eleventh annual conference and exhibition to be held at the Palmer House, Chicago, Ill. A. B. Campbell, 1061 M & M Bldg., Houston 2, Texas is executive secretary.

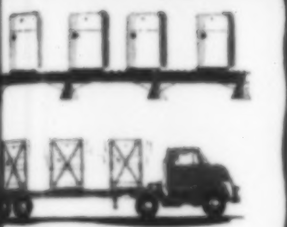
Mar. 10-11—

Porcelain Enamel Institute. Pacific Coast conference to be held at the Biltmore Hotel, Los Angeles, Calif. Additional information may be obtained from society headquaters, Dupont Circle Bldg., 1346 Connecticut Ave., N. W., Washington, D. C.

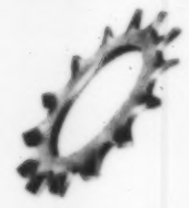
Mar. 14-15—

Steel Founders' Society. Annual meeting to be held at the Drake Hotel, Chicago, Ill. Additional information may be obtained from society headquarters, 920 Midland Bldg., Cleveland, O.

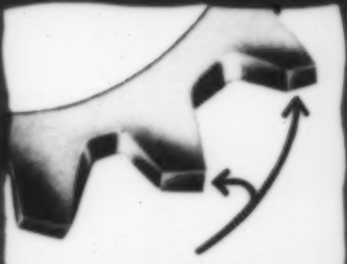
Why
SHAKEPROOF® LOCK WASHERS
defeat vibration!



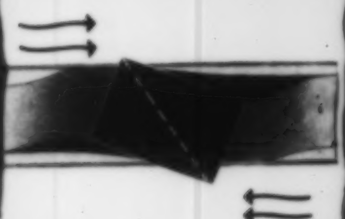
e purpose of lock washers is to keep screws and nuts tight.



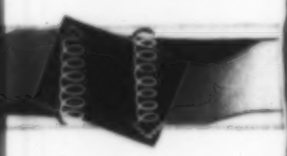
Shakeproof Lock Washers provide positive locking action that ordinary washers cannot give.



Only Shakeproof Lock Washers have these exclusive tapered-twisted teeth . . .

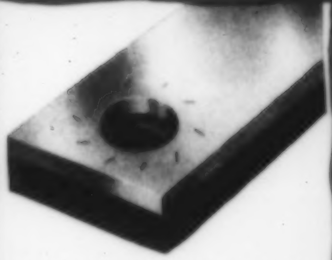


where each tooth is a strut to resist all loosening rotation of threaded fastening.

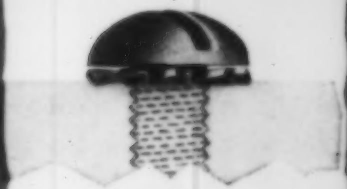


Spring tension forces the edges of each tooth to bite deeper.

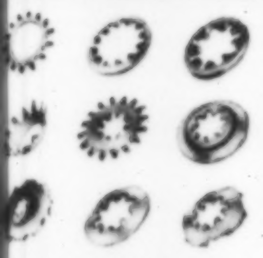
Shakeproof Lock Washers lock tighter as vibration increases . . .



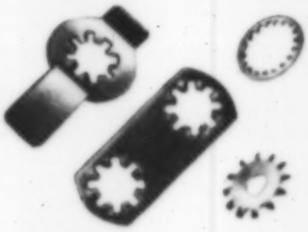
and the locking power of each tooth is multiplied by the number of teeth.



Their exclusive mechanical lock resists loosening as no other lock washer can!



o meet the majority of your locking needs, there are nine standard types.



The variety and styles of "specials" to meet individual requirements are unlimited!

For maximum savings, buy Shakeproof Lock Washers pre-assembled on screws as SEMS.

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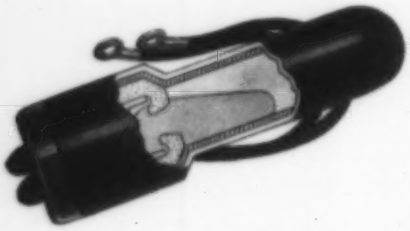

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MEN

OF MACHINES

As the first move in an expansion program, Cleveland Crane & Engineering Co., Wickliffe, O., has appointed **Roy Dehn** to the newly created position of director of engineering. Formerly chief engineer of the Heavy Machinery Div., Mr. Dehn has been associated with Cleveland Crane since 1937. For 17 years previously he was with the Industrial Brownhoist Co.

Roy Dehn

Succeeding Mr. Dehn, **Alfred W. Schultz** will be in charge of heavy overhead traveling crane, press and shear engineering. Mr. Schultz was formerly chief engineer and sales manager of the Cleveland Punch & Shear Works Co.

Worthington Corp., Harrison, N. J., has announced the appointment of **Joseph B. Inferrera** as executive engineer, with headquarters at the Wellsville, N. Y., plant. He was formerly chief mechanical design engineer. Mr. Inferrera joined Worthington in 1937 as a turbine design engineer and served successively as chief draftsman and then mechanical design engineer before being named chief mechanical design engineer in 1947.

Robert Howard has been appointed manager of the Vic-Dar Div. of Victor Adding Machine Co., Chicago. He has gained extensive engineering and production administration experience both with RCA and as manager of the government division of Webster-Chicago Corp.

Morse Chain Co., a Borg-Warner Corp. subsidiary operating plants in Ithaca, N. Y., and Detroit, has announced that **Norman C. Bremer,** previously chief engineer at Ithaca, has assumed the additional duties of chief engineer at the Detroit plant.

H. D. Emmert has been appointed assistant chief engineer of the steam turbine section, power department of Allis-Chalmers Mfg. Co., Milwaukee. Mr. Emmert joined the company's graduate student training course in 1937 and since that time has been associated with steam turbines and similar equipment. Last year he was named engineer-in-charge of development for the steam turbine section.

Chance Vought Aircraft Inc., Dallas, Tex., has promoted **Fred N. Dickerman** from chief engineer to the newly created position of director of engineering. **Raymond C. Blaylock,** formerly assistant chief engineer, was named chief engineer.

R. E. Gould has been named assistant chief engineer in charge of the research and future products division of Frigidaire Div. of Gen-

(Continued on Page 56)

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Men of Machines

(*Continued from Page 52*)

eral Motors Corp., Dayton, O. Concurrently, **H. E. Van Scoyck** was named assistant chief engineer of the commercial and air conditioning engineering divisions, and **E. F. Schweller** was appointed assistant chief engineer of the household engineering division.

The Trane Co., La Crosse, Wis., has appointed **George P. Staats** assistant development engineer.

The Aircraft Engine Div. of Ford Motor Co., Chicago, has announced the appointment of **Robert Insley** as chief product engineer. He has been manufacturing vice president of Continental Aviation & Engineering Corp.

Ralph A. Rockwell has been appointed chief engineer for the Valve Div. of Minneapolis-Honeywell Regulator Co., Minneapolis. Formerly technical consultant to the division, Mr. Rockwell will continue to serve as adviser to the engineering department.

J. A. Ackermann has been appointed chief engineer of the Elwell-Parker Electric Co., Cleveland. He joined the company in 1923 as a draftsman, was appointed chief draftsman in 1943 and assistant chief engineer in 1946. Mr. Ackermann participated in the design of early fork trucks, the first heavy-

J. A. Ackermann

duty ram trucks used by the steel industry, and the first rotary roll paper clamp.

Acme Steel Co., Chicago, has elected **Walter F. Hinkle** to the position of vice president of engineering. Mr. Hinkle will continue to direct all engineering activities for the company and will also be in charge of the mechanical and electrical divisions. Having joined Acme in 1926, Mr. Hinkle was named director of engineering in 1950 and director of engineering and research in 1953.

Capt. Charles Antoniak, USN (ret.), has joined Solar Aircraft Co., San Diego, Calif., as engineering consultant on power plants.

Formation of a Plate and Tank Div. at its Sunnyvale, Calif., plant has been announced by Wooldridge Mfg. Co. **Roman V. Gankin** was named head of the new division. Mr. Gankin is a specialist in thermodynamics and the design and construction of pressure vessels, heat exchangers and other specialized fabricated products.

Patrick E. Lannan recently was elected vice president of Designers for Industry Inc., Cleveland.

Precision Thermometer & Instrument Co., Philadelphia, has announced the appointment of **George M. Cleary** as chief engineer.

Robert W. Bowman has been appointed chief industrial engineer of Aeroquip Corp., Jackson, Mich.

Hugh Pruss has joined Audio Products Corp., Los Angeles, as head of telemetering research and development. He was formerly technical operations director and chief engineer of the Telemetering Div. of Raymond Rosen Engineering Products Inc.

Francis L. Woods has been appointed manager of engineering for the Distribution Transformer Dept. of General Electric Co. at Pittsfield, Mass.

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resist higher pressures
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Kennametal has a Young's Modulus of Elasticity of 60 to 90 million psi—2½ to 3 times that of the hardest steel. Hence, deformation of Kennametal Balls is only ⅓ to ½ that of steel. They have much greater resistance to abrasion and withstand the corrosive attack of many reagents.

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3/16	3/8	1/2	11/16
$1.28	$2.86	$3.62	$5.70

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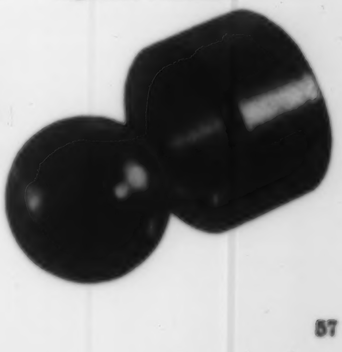

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says Service Caster & Truck Corporation

"The WEBSTER Hydraulic Pump has been very satisfactory. It is easy to install because the drive gear is an integral part of the pump drive shaft. This is an economy feature; we save time installing the unit, and eliminate the problems of a keyed assembly.

"Another reason we use the WEBSTER pump is that it is lower priced than most of the others available for this particular installation. It helps us get the contract.

"This WEBSTER Hydraulic Pump compares favorably with the pumps that we've used previously . . . and saves us money two ways."

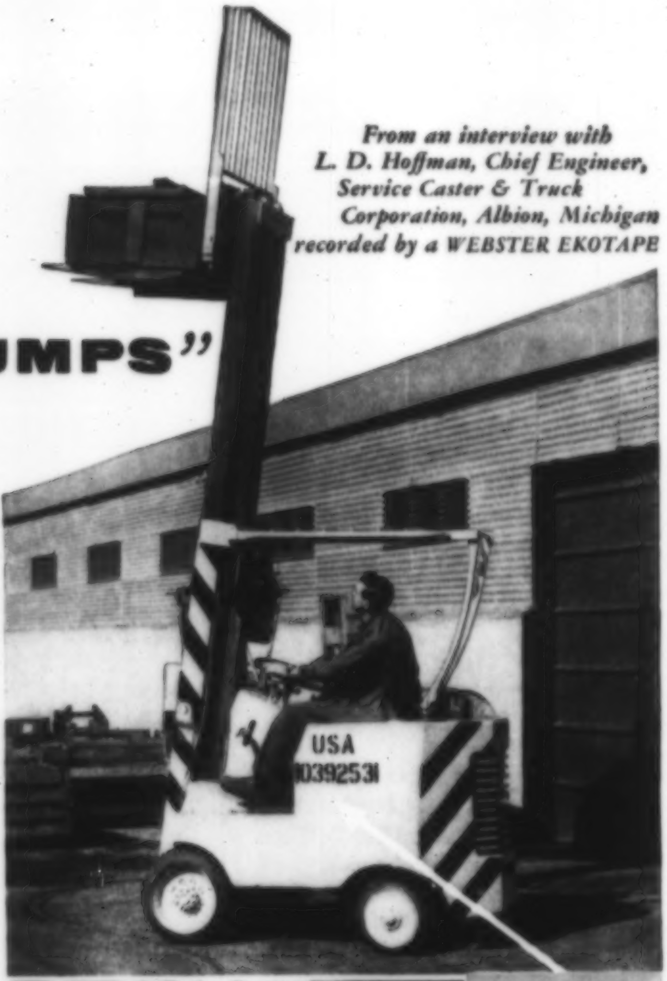
Choose from WEBSTER'S 90 types

The type HC WEBSTER Hydraulic Pump used by Service Caster is but one of 90 types of positive displacement gear pumps with capacities from 1/6 gpm to 30 gpm—at pressures up to 1200 psi—speeds to 3600 rpm—with or without relief valves—for sealed or wet sump mounting.

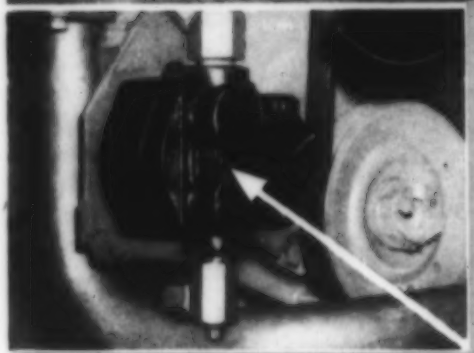
One of these custom-built units may well be the answer to your particular application. They are highly adaptable to a wide variety of uses in oil hydraulic systems.

Write us today for a catalog which contains illustrations, descriptions, performance charts, and pump data sheets on which you can tell us your requirements.

From an interview with
L. D. Hoffman, Chief Engineer,
Service Caster & Truck
Corporation, Albion, Michigan
recorded by a WEBSTER EKOTAPE



S4024 4000-lb. fork lift truck, made to U. S. Navy specifications for the Army by Service Caster & Truck Corp., is equipped with a WEBSTER Hydraulic Pump



Here you see how the type HC WEBSTER pump is attached for direct drive from engine of Service Caster-built fork lift truck

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MACHINE DESIGN
JANUARY 1955

Specialist or General Practitioner?

AMONG skilled occupations, that of racehorse pilot must be one of the most highly specialized. But H. Allen Smith tells us that a jockey worries about being so ignorant of anything beyond how to stay on a horse. To offset his embarrassment in cultured society, he picks some subject remote from his calling and proceeds to become an expert by reading everything ever published on that subject. Then as he sits with high-class people he maneuvers the conversation around to his subject. Thus he gets his moment in the limelight as the reigning expert on, for example, Chinese mortuary jade.

It is good for a man's morale to have a specialty, to know more about something than his fellows. There is also a measure of security in being so expert in a particular field or subject that a man's services are valued and in demand.

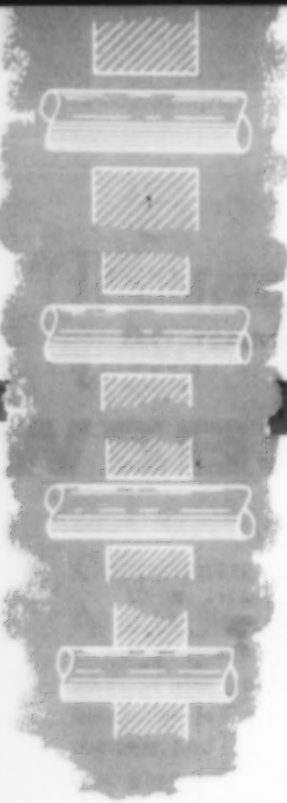
An engineer's personal professional development needs a fine blend of specialization with general practice. In this day of specialization, mediocre knowledge and skill in a specialty will not suffice. A man must know, through reading and association, what his fellow experts are doing in the same field. And he must tell the world, through publication, what he is doing to justify his claim to authority.

But in the struggle to develop his specialty the engineer is in danger of neglecting the well-balanced background of general design engineering practice so essential to creative endeavor. Sometimes an engineer is heard to deplore the number, size and frequency of engineering publications. This could be one of the danger signals.

Of course, the engineer with a specialty or a specific problem eagerly scans all pertinent publications for news of his subject or for immediate help. But the preponderance of published material—editorial and advertising—is for the general practitioner. To make the most of it should be regarded as a challenge rather than a chore. Whether it seems of immediate value or not, it builds up a background of priceless worth on the current job. Equally important, it serves as insurance against the time when a man's specialty no longer commands an easy market.

The competent general practitioner always eats.

Colin Carmichael
EDITOR



Standard Fits and

By Roger W. Bolz *Contributing Editor, Machine Design*

FOR many years there has been a great deal said and done concerning fits and limits. Strenuous efforts have been made to standardize on a basic integrated series of fits and limits. Yet little ground has been gained, no common standard of practice exists, and little is really known about the subject which can be put on paper with assurance.

Why? From the tremendous amount of experience gained through actual design and service, much should be known. Yet in no instance can any really detailed and documented factual data be found. Granted, the correlation of factual data on an unbiased basis is time-consuming and expensive. But it is of such critical importance in design that it is really difficult to understand why it has never been done.

Some Fit Problems: Analyzing the "whys" and "wherefores" of the situation expose several factors that require careful consideration before any steps are taken. First, and perhaps foremost, is a factor which has beclouded the path to a straightforward answer—the designer's overriding hesitancy to hew to any one line.

It has been a common thing for a long time to hear the acid comment concerning tolerances — "designers think of the smallest number they know and then halve it for the tolerance." Failure to specify rational and practical tolerances on many drawings has produced a strange situation. In many plants parts are produced from drawings without fit specifications or are produced to tolerances that "get by" but in no way agree with the drawing figures. The result is that often there is no basis for judgment of fact since the real situation seldom filters back to the engineering department for thorough analysis and study.

In other instances old designs and tools set the standards and many an engineer's rightful attitude becomes one of *laissez-faire*. In addition, with little time or wherewithal to delve into the complete problem there is an impossible wall to scale.

Beclouding of the issue has arisen to some extent over the approach to the problem. The key factor of the clearance or allowance—positive or negative—has always been submerged by the relatively simple and relatively fixed problem of tolerance. In a welter of figures for tolerances, the useful and needed data on the allowance or clearance have often been lost. Why?

Tolerances, unlike allowances, are not subject to guesswork or formulas or even neatly devised and graded tables. Tolerances are set and produced to verifiable values by production equipment available. The process used for reproduction of the part sets the tolerance range which can be practicably employed.

Completing the picture are all the many systems propounded to date and published in numerous books. None are ever rescinded, the books continue on the shelves, and the decision as to which system to use is impossible to make. Even today, books are submitted for publication carrying the original ASA Standard of 1925 which has long since been abandoned!

Why complicate a straightforward engineering problem? The aim must be to simplify! And it can be done. For the neophyte, for the practicing designer moving into new fields, and for economy, a rational approach can be taken.

A Survey of Today's Practices: MACHINE DESIGN has long been vitally interested in promoting better understanding and knowledge of fits and limits. Numerous surveys and discussions with engineers

Tolerances

Are standard fits possible?

What are the attitudes of industry?

Here are the results of an across-industry survey on this proverbial but critical problem.

The answer here presented is a practical standard compatible with the needs of the whole cross section of industry.

in industry have been concerned with this problem. The results have been somewhat less than world-shattering. Yet today some facts can be outlined in an endeavor to carry this problem further toward a suitable answer.

A study of practices across a great many industries has provided basic information from which certain major conclusions can be drawn:

1. Almost all companies contacted showed a real interest in this problem and expressed the conviction that improved data could be developed.
2. There is little or no generally apparent correlation among the practices of the companies studied, even though basically similar problems were being met. This conclusion is based on practices indicated by drawing values or standards only, which may or may not be the actual values produced in the shop in some instances.
3. From the wide range of values employed in a variety of cases where similar equipment was designed and problems were being met, it seemed fairly obvious that the insistence on finely divided allowances according to size was based on a fundamental error in judgment. Equal service and functional success were being experienced by all.
4. Many companies follow no specific practices, believing that no applicable data for common usage can be developed.
5. Some companies still follow the long-time practice of depending on the shop to determine needed fits.
6. To a strong degree the indication seemed to be that more often than not only a few basic fits were used. No more were needed.
7. Where specific practices and standards were in force, the type of data used ranged from greatly detailed information with fine divisions to simple groups of clearances only.
8. Finally, the ultimate conclusion seemed to be that a workable standard of completely detailed fits and limits was no more than an ill-founded hope without a remote chance of success. But, a detailed study revealed a really closer correlation than the welter of separate figures first indicated.

Admitting first that in all probability there will be certain instances *always* which will require special development of proper fits, yet could there not be a standard developed which would adequately cope with the *major* portion of *common* problems? We think so. Based on the fact that so many machines are today successfully operating without benefit of any real analysis of fits, this is a rational conclusion.

Analyzing the Problem: In study and analysis of the overall problem, two points seem clear. First, any standard to be developed must of necessity be designed to cover the selection of fits—meaning the right allowance or clearance range to be used. Second, it must provide a listing of tolerances *practicable*. Because economy in production is so vitally concerned with the problem of maintaining suitable tolerances, it is imperative that the designer be able to select the broadest possible tolerances that will provide a suitable practical clearance or allowance range.

Several key factors enter the picture which help obsolete forever any attempt to standardize rigidly on the major basis of tolerance only. This factor is statistical quality control. Through this means a desired mean positive allowance can be held in assembly even though the actual tolerance zones overlap.

Table 1—Preferred Basic Sizes

	0.0100	5/16	0.3125	1 7/8	1.8750
	0.0125	3/8	0.3750	2	2.0000
1/64	0.01562	7/16	0.4375	2 1/8	2.1250
	0.0200	1/2	0.5000	2 1/4	2.2500
	0.0250	9/16	0.5625	2 3/8	2.3750
1/32	0.03125	5/8	0.6250	2 1/2	2.5000
	0.0400	11/16	0.6875	2 5/8	2.6250
	0.0500	3/4	0.7500	2 3/4	2.7500
1/16	0.0625	7/8	0.8750	2 7/8	2.8750
	0.0800	1	1.0000	3	3.000
3/32	0.09375	1 1/8	1.1250	3 1/4	3.2500
	0.1000	1 1/4	1.2500	3 1/2	3.5000
1/8	0.1250	1 3/8	1.3750	3 3/4	3.7500
5/32	0.15625	1 1/2	1.5000	4	4.000
3/16	0.1875	1 5/8	1.6250		
1/4	0.2500	1 3/4	1.7500		

Another extremely important factor in this critical area of fits concerns the problem of part geometry. It is important to consider the fact that size tolerances on a hole or a shaft in no way define the roundness, straightness, or other characteristics of hole geometry. Close tolerances which fail to control hole geometry in no way guarantee that parts will actually assemble as desired.

Included in this problem is the difficult part of gaging requirements. As tolerances decrease, the gaging problem becomes rapidly more and more difficult and expensive—to the point where even the best production equipment cannot solve the problem. For all but the most demanding and critical designs, therefore, loose simplified fits should be investigated for suitability.

One final factor also to be considered concerns surface roughness values on parts to be assembled. Present standards tables take no cognizance of this problem but it nevertheless is of vital concern. Because the common production processes employed

Fundamental Terminology

TOLERANCE: Amount of variation permitted in size; the difference between the two limits.

LIMITS: Extreme permissible dimensions. Their difference is the tolerance.

ALLOWANCE: Intentional difference in the dimensions of mating parts; that is, the minimum clearance (or maximum interference) intended between mating parts. It is the tightest permissible fit, obtained when the largest internal member is mated with the smallest external member. Graduation of allowances provides for different classes of fit.

NOMINAL SIZE: Designation given to the subdivision of the unit of length having no specified limits of accuracy and being usually a standard or convenient dimension.

BASIC SIZE: Exact theoretical size from which all variations are stated.

Classes of Fit

Long practice has led to the arbitrary subdivision of the practical allowance range into eight classes. These are the traditional descriptions of those classes.

1. *LOOSE FIT—LARGE ALLOWANCE:* Provides for conconsiderable freedom, where accuracy is not essential, such as for machined fits of general machinery.
2. *FREE FIT—LIBERAL ALLOWANCE:* For running fits with speeds of 600 rpm or over and journal pressures of 600 psi or over. Usually used on generators, engines, many machine tool parts and some automotive parts.
3. *MEDIUM FIT—MEDIUM ALLOWANCE:* For running fits under 600 rpm and with journal pressures less than 600 psi; also for sliding fits and the more accurate machine-tool and automotive parts.
4. *SNUG FIT—ZERO ALLOWANCE:* Closest fit which can be assembled by hand. Necessitates work of considerable precision. Should be usede where no perceptible shake is permissible and where moving parts are not intended to move freely under load.
5. *WRINGING FIT—ZERO TO NEGATIVE ALLOWANCE:* Known also as a "tunking fit" and is practically metal-to-metal. Assembly is usually selective and is not interchangeable.
6. *TIGHT FIT—SLIGHT NEGATIVE ALLOWANCE:* Light pressure is required to assemble parts which are more or less permanently assembled, such as the fixed ends of studs for gears, pulleys, rocker arms, etc. Used for drive fits in thin sections or extremely long fits in other sections and also for shrink fits on very light sections.
7. *MEDIUM FORCE FIT—NEGATIVE ALLOWANCE:* Considerable pressure is required to assemble parts which are considered permanently assembled. Used in fastening locomotive wheels, car wheels, armatures of generators and motors, and crank disks to their axles or shafts. Also used for shrink fits on medium sections or long fits. Tightest recommended for cast-iron holes or external members since they stress cast iron to its elastic limit.
8. *HEAVY FORCE FIT—CONSIDERABLE NEGATIVE ALLOWANCE:* For steel holes where the metal can be highly stressed without exceeding its elastic limit. Cause excessive stress for cast-iron holes. Shrink fits are used where heavy force fits are impractical, as on locomotive wheel tires, heavy crank disks of large engines, etc.

produce within a certain specific roughness band which can be readily determined, proper tolerance tables can reflect this factor in the specifications.

Developing a Solution: To start, clarification of terminology is needed. This has been a major problem in standardization and specific definitions are required to insure that always the correct terms are employed. Here, few of the people consulted agreed—ideas vary but this is good in engineering. However, careful study indicated what specifically was intended. Basic terms and classes of fit are defined in the accompanying box. Thus the basis for further development of the problem is set.

Thus, the first problem at hand is to arrive at a suitable arrangement of workable allowances. These, of course, will be suitable primarily for general-purpose fits and conditions. From the foregoing considerations and the study made, it is obvious that fits for general-purpose application should encompass only nominal lengths of fit. Perhaps a limit from one to one and one-half diameters would be considered maximum. With this consideration, a common arrangement of tolerances could absorb the nominal geometrical variations to be expected. In large sizes and longer lengths of fit, special consideration would be necessary to assure proper fits.

Where peculiar problems or unknowns are encountered, some experimentation will be required to insure the most practical fits.

Once a suitable allowance range is selected it is possible to apply a standard tolerance. The tolerance, however, should then be checked against available processing tolerances. In this way the most economical processing method available can be insured.

Procedure to Results: The first step in the procedure is to consider selection of a preferred basic size or diameter. In *Table* 1 are listed preferred sizes for diameters up to 4 inches. Sizes beyond 4 inches advance by ¼-inch steps to 6 inches and by ½-inch steps above 6 inches.

Second step to consider is that of preferred values of tolerances and allowances. In *Table* 2 are shown recommended preferred values. In general

Table 2—Preferred Tolerances and Allowances

0.0001	0.0010	0.0100
	0.0012	0.0120
0.00015	0.0015	0.0150
0.0002	0.0020	0.0200
0.00025	0.0025	0.0250
0.0003	0.0030	0.0300
0.0004	0.0040	
0.0005	0.0050	
0.0006	0.0060	
0.0008	0.0080	

Table 3—Consolidated Field Data on Fits

Nom. Fit Diam.	Hole Diam.	Hole Tol.	Shaft Diam.	Shaft Tol.	Clearance Min.	Clearance Max.
Production Grade Commercial Shafts						
To 1 in.	Nom. + .003	+ .001 — .001	Nom.	+ .000 — .002	.002	.006
Over 1 to 2	Nom. + .005	+ .001 — .002	Nom.	+ .000 — .003	.003	.009
Over 2 to 4	Nom. + .007	+ .002 — .003	Nom.	+ .000 — .004	.004	.013
Over 4 to 6	Nom. + .008	+ .002 — .003	Nom.	+ .000 — .005	.005	.015
Commercial tolerances shown for shafts of steel (cold-finished rounds) to 0.30 per cent carbon. Steels from 0.31 to 0.50 per cent carbon have minus tolerance increased 0.001 inch. Hole tolerances represent average production.						
Production Grade Drilled						
To 1/16 in.	Nom.	+ .003 — .001	Nom. — .004	+ .002 — .002	.001	.009
Over 1/16 to ⅛	Nom.	+ .004 — .001	Nom. — .004	+ .002 — .002	.001	.010
Over ⅛ to ¼	Nom.	+ .005 — .001	Nom. — .004	+ .002 — .002	.001	.011
Over ¼ to ½	Nom.	+ .006 — .001	Nom. — .004	+ .002 — .002	.001	.012
Over ½ to ¾	Nom.	+ .007 — .002	Nom. — .005	+ .002 — .002	.001	.014
Over ¾ to 1	Nom.	+ .008 + .002	Nom. — .005	+ .002 — .002	.001	.015
Over 1 to 2	Nom.	+ .010 — .002	Nom. — .007	+ .003 — .003	.002	.020
Drilled holes, production standard. Shaft tolerances, turned production grade.						
Loose—Common Grade						
To 1 in.	Nom.	+ .0005 — .0010	Nom. — .0020	+ .0000 — .0030	.0010	.0055
Over 1 to 2	Nom.	+ .0005 — .0010	Nom. — .0030	+ .0000 — .0040	.0020	.0075
Over 2 to 3½	Nom.	+ .0005 — .0010	Nom. — .0040	+ .0000 — .0050	.0030	.0095
Over 3½ to 6	Nom.	+ .0005 — .0010	Nom. — .0060	+ .0000 — .0070	.0050	.0135
Hole standard, good production reamed or bored. Shaft tolerances turned high grade.						
Free Precision Grade						
To 1 in.	Nom.	+ .0005 — .0005	Nom. — .0010	+ .0000 — .0020	.0005	.0035
Over 1 to 2	Nom.	+ .0005 — .0005	Nom. — .0015	+ .0000 — .0020	.0010	.0040
Over 2 to 3½	Nom.	+ .0005 — .0005	Nom. — .0025	+ .0000 — .0030	.0020	.0060
Over 3½ to 6	Nom.	+ .0005 — .0005	Nom. — .0035	+ .0000 — .0040	.003	.0080
Hole standard, precision reamed or bored. Shaft tolerances precision turned.						
Medium Precision Grade—High Speed						
To ½-in.	Nom.	+ .0005 — .0000	Nom. — .0005	+ .0000 — .0005	.0005	.0015
Over ½ to 1	Nom.	+ .0005 — .0000	Nom. — .001	+ .0000 — .0010	.001	.0025
Over 1 to 2	Nom.	+ .0005 — .0000	Nom. — .002	+ .0000 — .0010	.002	.0035
Over 2 to 3½	Nom.	+ .0005 — .0000	Nom. — .003	+ .0000 — .0010	.003	.0045
Over 3½ to 6	Nom.	+ .0005 — .0000	Nom. — .004	+ .0000 — .0015	.004	.0060
Hole standard, precision ground, broached or bored. Shaft tolerances precision ground.						
Fine Precision Grade—Low Speeds						
To 1 in.	Nom.	+ .0005 — .0000	Nom. — .0005	+ .0000 — .0005	.0005	.0015
Over 1 to 2	Nom.	+ .0005 — .0000	Nom. — .0015	+ .0000 — .0010	.0015	.0030
Over 2 to 3½	Nom.	+ .0005 — .0000	Nom. — .0020	+ .0000 — .0010	.0020	.0035
Over 3½ to 6	Nom.	+ .0005 — .0000	Nom. — .0025	+ .0000 — .0015	.0025	.0045
Hole standard, precision ground, honed, broached or bored. Shaft tolerances precision ground.						

the data in *Tables* 1 and 2 conform to ASA recommendations and fairly common practice.

To develop the true picture of the range of fits in use today, a complete listing of allowances or clearances was made from the data which were supplied. From this base a complete set of clearance fits was developed. The data are shown in *Table* 3.

These tables were developed from the ranges of allowances derived through careful study of the data and suitable tolerances developed from basic production data. Thus, most of the figures were set and the remaining ones calculated and corrected to suit production tolerance data.

A New But Complete System: These data in *Table* 3, therefore, could represent the practical reduction of practice across many industries with the variables adjusted to general conformance. Here, then, was a new set of data on fits. More confusion might be the answer! But no, the aim was not to develop new data but to produce com-

Table 4—Recommended Standard Tolerances and Fits

Class 1—Loose Fit

Basic Hole System | **Basic Shaft System**

Nom. Diam.	Standard Quality		Special Quality		Allow.	Standard Quality		Special Quality	
	Hole	Shaft	Hole	Shaft		Shaft	Hole	Shaft	Hole
1/32	.0312 + .0050	.0292 − .0050	.0312 + .0020	.0292 − .0020	.002	.0312 − .0050	.0314 + .0050	.0312 − .0020	.0314 + .0020
.0400	.040 + .005	.038 − .005	.040 + .002	.038 − .002	.002	.040 − .005	.042 + .005	.040 − .002	.042 + .002
.0500	.050 + .005	.048 − .005	.050 + .002	.048 − .002	.002	.050 − .005	.052 + .005	.050 − .002	.052 + .002
1/16	.0625 + .0050	.0605 − .0050	.0625 + .0020	.0605 − .0020	.002	.0625 − .0050	.0645 + .0050	.0625 − .0020	.0645 + .0020
.0800	.080 + .005	.078 − .005	.080 + .002	.078 − .002	.002	.080 − .005	.082 + .005	.080 − .002	.082 + .002
3/32	.0937 + .0050	.0917 − .0050	.0937 + .0020	.0917 − .0020	.002	.0937 − .0050	.0957 + .0050	.0937 − .0020	.0957 + .0020
.1000	.100 + .005	.098 − .005	.100 + .002	.098 − .002	.002	.100 − .005	.102 − .005	.100 − .002	.102 + .002
⅛	.125 + .005	.123 − .005	.125 + .002	.123 − .002	.002	.125 − .005	.127 + .005	.125 − .002	.127 + .002
5/32	.1562 + .0050	.1542 − .0050	.1562 + .0020	.1542 − .0020	.002	.1562 − .0050	.1582 + .0050	.1562 − .0020	.1582 + .0020
3/16	.1875 + .0050	.1855 − .0050	.1875 + .0020	.1855 − .0020	.002	.1875 − .0050	.1895 + .0050	.1875 − .0020	.1895 + .0020
¼	.250 + .005	.248 − .005	.250 + .002	.248 − .002	.002	.250 − .005	.252 + .005	.250 − .002	.252 + .002
5/16	.3125 + .0050	.3105 − .0050	.3125 + .0020	.3105 − .0020	.002	.3125 − .0050	.3145 + .0050	.3125 − .0020	.3145 + .0020
⅜	.375 + .005	.373 − .005	.375 + .002	.373 − .002	.002	.375 − .005	.377 + .005	.375 − .002	.377 + .002
½	.500 + .005	.498 − .005	.500 + .002	.498 − .002	.002	.500 − .005	.502 + .005	.500 − .002	.502 − .002
9/16	.5625 + .0050	.5605 − .0050	.5625 + .0020	.5605 − .0020	.002	.5625 − .0050	.5645 + .0050	.5625 − .0020	.5645 + .0020
⅝	.625 + .006	.6225 − .0060	.6250 + .0025	.6225 − .0025	.0025	.625 − .006	.6275 + .0060	.6250 − .0025	.6275 + .0025
¾	.750 + .006	.7475 − .0060	.7500 + .0025	.7475 − .0025	.0025	.750 − .006	.7525 + .0060	.7500 − .0025	.7525 + .0025
⅞	.875 + .006	.8725 − .0060	.8750 + .0025	.8725 − .0025	.0025	.875 − .006	.8775 + .0060	.8750 − .0025	.8775 + .0025
1	1.000 + .008	.997 − .008	1.000 + .003	.997 − .003	.003	1.000 − .008	1.003 + .008	1.000 − .003	1.003 + .003
1¼	1.250 + .008	1.247 − .008	1.250 + .003	1.247 − .003	.003	1.250 − .008	1.253 + .008	1.250 − .003	1.253 + .003
1½	1.500 + .010	1.496 − .010	1.500 + .004	1.496 − .004	.004	1.500 − .010	1.504 + .010	1.500 − .004	1.504 + .004
2	2.000 + .010	1.996 − .010	2.000 + .004	1.996 − .004	.004	2.000 − .010	2.004 + .010	2.000 − .004	2.004 + .004
2½	2.500 + .010	2.496 − .010	2.500 + .004	2.496 − .004	.004	2.500 − .010	2.504 + .010	2.500 − .004	2.504 + .004
3	3.000 + .012	2.995 − .012	3.000 + .005	2.995 − .005	.005	3.000 − .012	3.005 + .012	3.000 − .005	3.005 + .005
3½	3.500 + .012	3.495 − .012	3.500 + .005	3.495 − .005	.005	3.500 − .012	3.505 + .012	3.500 − .005	3.505 + .005
4	4.000 + .012	3.995 − .012	4.000 + .005	3.995 − .005	.005	4.000 − .012	4.005 + .012	4.000 − .005	4.005 + .005
5	5.000 + .015	4.994 − .015	5.000 + .006	4.994 − .006	.006	5.000 − .015	5.006 + .015	5.000 − .006	5.006 + .006
6	6.000 + .015	5.994 − .015	6.000 + .006	5.994 − .006	.006	6.000 − .015	6.006 + .015	6.000 − .006	6.006 + .006
8	8.000 + .020	7.992 − .020	8.000 + .008	7.992 − .008	.008	8.000 − .020	8.008 + .020	8.000 − .008	8.008 + .008
10	10.000 + .020	9.992 − .020	10.000 + .008	9.992 − .008	.008	10.000 − .020	10.008 + .020	10.000 − .008	10.008 + .008

Class 2—Free Fit

Basic Hole System | **Basic Shaft System**

Nom. Diam.	Standard Quality		Special Quality		Allow.	Standard Quality		Special Quality	
	Hole	Shaft	Hole	Shaft		Shaft	Hole	Shaft	Hole
.016	.0160 + .0012	.0152 − .0012	.0160 + .0008	.0152 − .0008	.0008	.0160 − .0012	.0168 + .0012	.0160 − .0008	.0168 + .0008
.020	.0200 + .0012	.0192 − .0012	.0200 + .0008	.0192 − .0008	.0008	.0200 − .0012	.0208 + .0012	.0200 − .0008	.0208 + .0008
.025	.0250 + .0012	.0242 − .0012	.0250 + .0008	.0242 − .0008	.0008	.0250 − .0012	.0258 + .0012	.0250 − .0008	.0258 + .0008
1/32	.0312 + .0012	.0304 − .0012	.0312 + .0008	.0304 − .0008	.0008	.0312 − .0012	.0320 + .0012	.0312 − .0008	.0320 + .0008
.0400	.0400 + .0012	.0392 − .0012	.0400 + .0008	.0392 − .0008	.0008	.0400 − .0012	.0408 + .0012	.0400 − .0008	.0408 + .0008
.0500	.0500 + .0012	.0492 − .0012	.0500 + .0008	.0492 − .0008	.0008	.0500 − .0012	.0508 + .0012	.0500 − .0008	.0508 + .0008
1/16	.0625 + .0012	.0617 − .0012	.0625 + .0008	.0617 − .0008	.0008	.0625 − .0012	.0633 + .0012	.0625 − .0008	.0633 + .0008
.0800	.0800 + .0012	.0792 − .0012	.0800 + .0008	.0792 − .0008	.0008	.0800 − .0012	.0808 + .0012	.0800 − .0008	.0808 + .0008
3/32	.0937 + .0012	.0929 − .0012	.0937 + .0008	.0929 − .0008	.0008	.0937 − .0012	.0945 + .0012	.0937 − .0008	.0945 + .0008
.1000	.1000 + .0012	.0992 − .0012	.1000 + .0008	.0992 − .0008	.0008	.1000 − .0012	.1008 + .0012	.1000 − .0008	.1008 + .0008
⅛	.1250 + .0012	.1242 − .0012	.1250 + .0008	.1242 − .0008	.0008	.1250 − .0012	.1258 + .0012	.1250 − .0008	.1258 + .0008
5/32	.1562 + .0012	.1554 − .0012	.1562 + .0008	.1554 − .0008	.0008	.1562 − .0012	.1570 + .0012	.1562 − .0008	.1570 + .0008
3/16	.1875 + .0012	.1867 − .0012	.1875 + .0008	.1867 − .0008	.0008	.1875 − .0012	.1883 + .0012	.1875 − .0008	.1883 + .0008
¼	.2500 + .0012	.2492 − .0012	.2500 + .0008	.2492 − .0008	.0008	.2500 − .0012	.2508 + .0012	.2500 − .0008	.2508 + .0008
5/16	.3125 + .0012	.3117 − .0012	.3125 + .0008	.3117 − .0008	.0008	.3125 − .0012	.3133 + .0012	.3125 − .0008	.3133 + .0008
⅜	.3750 + .0012	.3742 − .0012	.3750 + .0008	.3742 − .0008	.0008	.3750 − .0012	.3758 + .0012	.3750 − .0008	.3758 + .0008
½	.5000 + .0012	.4992 − .0012	.5000 + .0008	.4992 − .0008	.0008	.5000 − .0012	.5008 + .0012	.5000 − .0008	.5008 + .0008
9/16	.5625 + .0012	.5617 − .0012	.5625 + .0008	.5617 − .0008	.0008	.5625 − .0012	.5633 + .0012	.5625 − .0008	.5633 + .0008
⅝	.6250 + .0015	.6240 − .0015	.625 + .001	.624 − .001	.001	.6250 − .0015	.6260 + .0015	.625 − .001	.626 + .001
¾	.7500 + .0015	.7490 − .0015	.750 + .001	.749 − .001	.001	.7500 − .0015	.7510 + .0015	.750 − .001	.751 + .001
⅞	.8750 + .0015	.8740 − .0015	.875 + .001	.874 − .001	.001	.8750 − .0015	.8760 + .0015	.875 − .001	.876 + .001
1	1.000 + .002	.9988 − .0020	1.0000 + .0012	.9988 − .0012	.0012	1.000 − .002	1.0012 + .0020	1.0000 − .0012	1.0012 + .0012
1¼	1.250 + .002	1.2488 − .0020	1.2500 + .0012	1.2488 − .0012	.0012	1.250 − .002	1.2512 + .0020	1.2500 − .0012	1.2512 + .0012
1½	1.5000 + .0025	1.4985 − .0025	1.5000 + .0015	1.4985 − .0015	.0015	1.5000 − .0025	1.5015 + .0025	1.5000 − .0015	1.5015 + .0015
2	2.0000 + .0025	1.9985 − .0025	2.0000 + .0015	1.9985 − .0015	.0015	2.0000 − .0025	2.0015 + .0025	2.0000 − .0015	2.0015 + .0015
2½	2.5000 + .0025	2.4985 − .0025	2.500 + .0015	2.4985 − .0015	.0015	2.5000 − .0025	2.5015 + .0025	2.5000 − .0015	2.5015 + .0015
3	3.000 + .003	2.998 − .003	3.000 + .002	2.998 − .002	.002	3.000 − .003	3.002 + .003	3.000 − .002	3.002 + .002
3½	3.500 + .003	3.498 − .003	3.500 + .002	3.498 − .002	.002	3.500 − .003	3.502 + .003	3.500 − .002	3.502 + .002
4	4.000 + .003	3.998 − .003	4.000 + .002	3.998 − .002	.002	4.000 − .003	4.002 + .003	4.000 − .002	4.002 + .002
5	5.000 + .004	4.9975 − .0040	5.0000 + .0025	4.9975 − .0025	.0025	5.000 − .004	5.0025 + .0040	5.0000 − .0025	5.0025 + .0025
6	6.000 + .004	5.9975 − .0040	6.0000 + .0025	5.9975 − .0025	.0025	6.000 − .004	6.0025 + .004	6.0000 − .0025	6.0025 + .0025
8	8.000 + .005	7.997 − .005	8.000 + .003	7.997 − .003	.003	8.000 − .005	8.003 + .005	8.000 − .003	8.003 + .003
10	10.000 + .005	9.997 − .005	10.000 + .003	9.997 − .003	.003	10.000 − .005	10.003 + .005	10.000 − .003	10.003 + .003

monly workable results from practice. The question was—with such figures developed from practical shop data and actual practice, was there a common ground in any present system?

Used as a check on practices in use today, there proved to be one. And, to all indications, there is a real basis for agreement—and agreement in the direction of a simplified group of fits readily usable by any group. *Table* 4 contains the complete series. All clearance fits are complete, in two quality ranges—standard for maximum economy, and special for maximum precision where added cost is not too great a factor. Here is a system which closely agrees with practice.

Where the very critical fits are covered, no tolerances are given. Thus, these fits can be dimensioned from available data to suit conditions. Under average manufacturing conditions it is cheaper and more efficient to fit these classes of mating parts at assembly rather than attempt to set up interchangeable ranges. Here selective assembly is more practical and suitable—and is being widely used for critical parts. And quality control methods can be used in certain of these instances to attain desired results.

Other Data: To simplify use of basic allowances, data are desirable on production tolerances. The chart in *Fig.* 1 shows generally how processes can be expected to range in terms of tolerances and surface finish. Where specific processes are being considered for production, the process to be used should be studied.[1] Some indication of how tolerances affect costs in production can be seen from a recent study made in this area.[2]

In addition, some study of fit stresses may be desirable where shrink and heavy press fits are used. Faupel has provided the most recent and complete study on the problem of shrink fits.[3]

Conclusions: Practices in this area of design have without question been subject to many variables and opinions. Perhaps now is the time to set the record straight for the benefit of all concerned. From an economy and an engineering standpoint, a practical basis on which to build is imperative.

The record indicates that wide variations in fit

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[1] References are tabulated at end of article.

Class 3—Running Fit

	Basic Hole System					Basic Shaft System			
Nom. Diam.	Standard Quality		Special Quality		Allow.	Standard Quality		Special Quality	
	Hole	Shaft	Hole	Shaft		Shaft	Hole	Shaft	Hole
.01	.0100 + .0008	.0097 — .0005	.0100 + .0005	.0097 — .0003	.0003	.0100 — .0005	.0103 + .0008	.0100 — .0003	.0103 + .0005
.0125	.0125 + .0008	.0122 — .0005	.0125 + .0005	.0122 — .0003	.0003	.0125 — .0005	.0128 + .0008	.0125 — .0003	.0128 + .0005
.016	.0160 + .0008	.0157 — .0005	.0160 + .0005	.0157 — .0003	.0003	.0160 — .0005	.0163 + .0008	.0160 — .0003	.0163 + .0005
.020	.0200 + .0008	.0197 — .0005	.0200 + .0005	.0197 — .0003	.0003	.0200 — .0005	.0203 + .0008	.0200 — .0003	.0203 + .0005
.025	.0250 + .0008	.0247 — .0005	.0250 + .0005	.0247 — .0003	.0003	.0250 — .0005	.0253 + .0008	.0250 — .0003	.0253 + .0005
1/32	.0312 + .0008	.0309 — .0005	.0312 + .0005	.0309 — .0003	.0003	.0312 — .0005	.0315 + .0008	.0312 — .0003	.0315 + .0005
.0400	.0400 + .0008	.0397 — .0005	.0400 + .0005	.0397 — .0003	.0003	.0400 — .0005	.0403 + .0008	.0400 — .0003	.0403 + .0005
.0500	.0500 + .0008	.0497 — .0005	.0500 + .0005	.0497 — .0003	.0003	.0500 — .0005	.0503 + .0008	.0500 — .0003	.0503 + .0005
1/16	.0625 + .0008	.0622 — .0005	.0625 + .0005	.0622 — .0003	.0003	.0625 — .0005	.0628 + .0008	.0625 — .0003	.0628 + .0005
.0800	.0800 + .0008	.0797 — .0005	.0800 + .0005	.0797 — .0003	.0003	.0800 — .0005	.0803 + .0008	.0800 — .0003	.0803 + .0005
3/32	.0937 + .0008	.0934 — .0005	.0937 + .0005	.0934 — .0003	.0003	.0937 — .0005	.0940 + .0008	.0937 — .0003	.0940 + .0005
.1000	.1000 + .0008	.0997 — .0005	.1000 — .0005	.0997 — .0003	.0003	.1000 — .0005	.1003 + .0008	.1000 — .0003	.1003 + .0005
⅛	.1250 + .0008	.1247 — .0005	.1250 + .0005	.1247 — .0003	.0003	.1250 — .0005	.1253 + .0008	.1250 — .0003	.1253 + .0005
5/32	.1562 + .0008	.1559 — .0005	.1562 + .0005	.1559 — .0003	.0003	.1562 — .0005	.1565 + .0008	.1562 — .0003	.1565 + .0005
3/16	.1875 + .0008	.1872 — .0005	.1875 + .0005	.1872 — .0003	.0003	.1875 — .0005	.1878 + .0008	.1875 — .0003	.1878 + .0005
¼	.2500 + .0008	.2497 — .0005	.2500 + .0005	.2497 — .0003	.0003	.2500 — .0005	.2503 + .0008	.2500 — .0003	.2503 + .0005
5/16	.3125 + .0008	.3122 — .0005	.3125 + .0005	.3122 — .0003	.0003	.3125 — .0005	.3128 + .0008	.3125 — .0003	.3128 + .0005
⅜	.3750 + .0008	.3747 — .0005	.3750 + .0005	.3747 — .0003	.0003	.3750 — .0005	.3753 + .0008	.3750 — .0003	.3753 + .0005
½	.5000 + .0008	.4997 — .0005	.5000 + .0005	.4997 — .0003	.0003	.5000 — .0005	.5003 + .0008	.5000 — .0003	.5003 + .0005
9/16	.5625 + .0008	.5622 — .0005	.5625 + .0005	.5622 — .0003	.0003	.5625 — .0005	.5628 + .0008	.5625 — .0003	.5628 + .0005
⅝	.625 + .001	.6246 — .0006	.6250 + .0006	.6246 — .0004	.0004	.6250 — .0006	.6254 + .0010	.6250 — .0004	.6254 + .0006
¾	.750 + .001	.7496 — .0006	.7500 + .0006	.7496 — .0004	.0004	.7500 — .0006	.7504 + .0010	.7500 — .0004	.7504 + .0006
⅞	.875 + .001	.8746 — .0006	.8750 + .0006	.8746 — .0004	.0004	.8750 — .0006	.8754 + .0010	.8750 — .0004	.8754 + .0006
1	1.0000 + .0012	.9995 — .0008	1.0000 + .0008	.9995 — .0005	.0005	1.0000 — .0008	1.0005 + .0012	1.0000 — .0005	1.0005 + .0008
1¼	1.2500 + .0012	1.2495 — .0008	1.2500 + .0008	1.2495 — .0005	.0005	1.2500 — .0008	1.2505 + .0012	1.2500 — .0005	1.2505 + .0008
1½	1.500 + .0015	1.4994 — .0010	1.500 + .001	1.4994 — .0006	.0006	1.500 — .001	1.5006 + .0015	1.5000 — .0006	1.5006 + .0010
2	2.0000 + .0015	1.9994 — .0010	2.000 + .001	1.9994 — .0006	.0006	2.000 — .001	2.0006 + .0015	2.0000 — .0006	2.0006 + .0010
2½	2.5000 + .0015	2.4994 — .0010	2.500 + .001	2.4994 — .0006	.0006	2.500 — .001	2.5006 + .0015	2.5000 — .0006	2.5006 + .0010
3	3.000 + .002	2.9992 — .0012	3.0000 + .0012	2.9992 — .0008	.0008	3.0000 — .0012	3.0008 + .0020	3.0000 — .0008	3.0008 + .0012
3½	3.500 + .002	3.4992 — .0012	3.5000 + .0012	3.4992 — .0008	.0008	3.5000 — .0012	3.5008 + .0020	3.5000 — .0008	3.5008 + .0012
4	4.000 + .002	3.9992 — .0012	4.0000 + .0012	3.9992 — .0008	.0008	4.0000 — .0012	4.0008 + .0020	4.0000 — .0008	4.0008 + .0012
5	5.0000 + .0025	4.9990 — .0015	5.0000 + .0015	4.999 — .001	.001	5.0000 — .0015	5.0010 + .0025	5.000 — .001	5.0010 + .0015
6	6.0000 + .0025	5.9990 — .0015	6.0000 + .0015	5.999 — .001	.001	6.0000 — .0015	6.0010 + .0025	6.000 — .001	6.0010 + .0015
8	8.000 + .003	7.9988 — .0020	8.000 + .002	7.9988 — .0012	.0012	8.000 — .002	8.0012 + .0030	8.0000 — .0012	8.0012 + .0020
10	10.000 + .003	9.9988 — .0020	10.000 + .002	9.9988 — .0012	.0012	10.000 — .002	10.0012 + .0030	10.0000 — .0012	10.0012 + .0020

Class 4—Slide Fit

Nom. Diam.	Max. Clear.	Nom. Diam.	Max. Clear.	Nom. Diam.	Max. Clear.	Nom. Diam.	Max. Clear.
		1/16	.0003	⅜	.0003	2	.0006
.01	.0003	.0800	.0003	½	.0003	2½	.0006
.0125	.0003	3/32	.0003	9/16	.0003	3	.0008
.016	.0003	.1000	.0003	⅝	.0004	3½	.0008
.020	.0003	⅛	.0003	¾	.0004	4	.0008
.025	.0003	5/32	.0003	⅞	.0004	5	.001
1/32	.0003	3/16	.0003	1	.0005	6	.001
.0400	.0003	¼	.0003	1¼	.0005	8	.0012
.0500	.0003	5/16	.0003	1½	.0006	10	.0012

Classes 5 to 8—Interference Fits

		Required Interference							
Size		Class 5 Wringing Fit		Class 6 Drive Fit		Class 7 Force Fit		Class 8 Heavy Force Fit	
From	To	From	To	From	To	From	To	From	To
.000	.599	0	.0003	.0003	.0005	.0008	.0012	.0015	.002
.600	.999	0	.0004	.0004	.0006	.001	.0015	.002	.0025
1.000	1.499	0	.0005	.0005	.0008	.0012	.002	.0025	.003
1.500	2.799	0	.0006	.0006	.001	.0015	.0025	.003	.004
2.800	4.499	0	.0008	.0008	.0012	.002	.003	.004	.005
4.500	7.799	0	.001	.001	.0015	.0025	.004	.005	.006
7.800	13.599	0	.0012	.0012	.002	.003	.005	.006	.008
13.600	20.999	0	.0015	.0015	.0025	.004	.006	.008	.010

of similar components have not seriously impaired success. A common basis for average design or for forming a starting point can be extremely useful. Based on practical manufacturing practices, this type of system cannot create the conditions of resistance met by many proposed systems. Simple in arrangement, it meets the test of everyday use by average personnel.

While economics may dictate adherence to some earlier standards in cases where expensive gaging equipment is involved, the way can be paved for future work by proper evolutionary change. A real advance can be made—no true engineering domain is invaded, worthwhile economies can be achieved, and a firm foundation upon which to build is erected.

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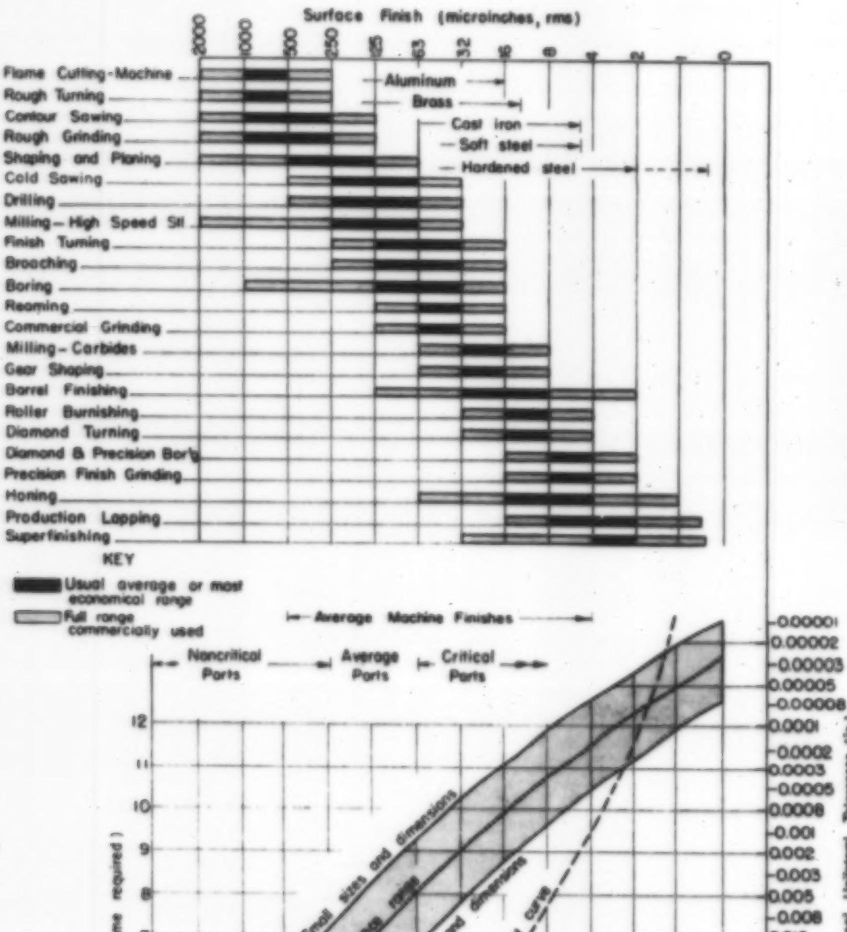
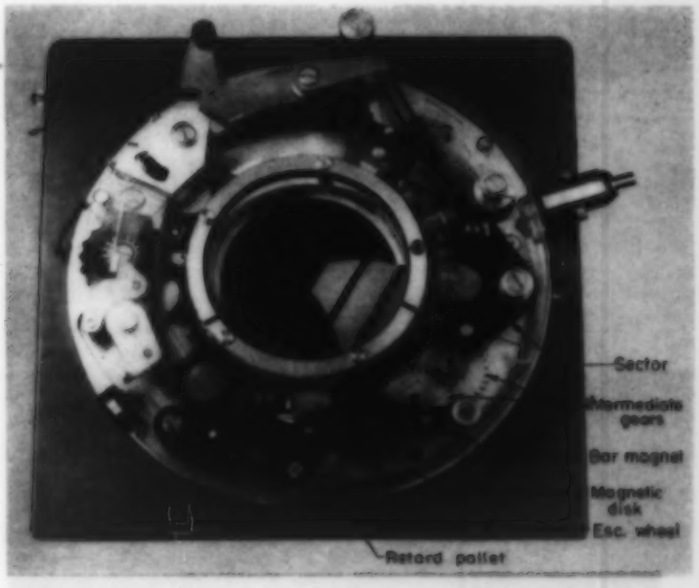


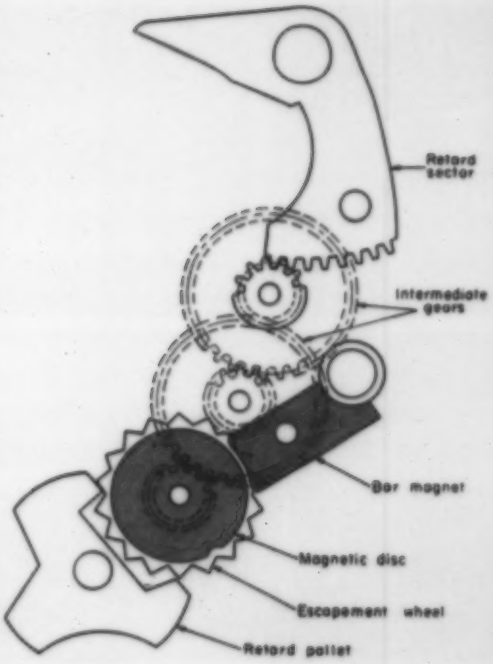
Fig. 1—Chart showing basic machining processes, their overall and normal commercial range of surface roughness, and their accompanying range of practical dimensional tolerances. Rational tolerance ranges are merely indicative and should not be applied without adequate study of the process under consideration

SCANNING the field for IDEAS

MAGNETIC BACKLASH CONTROL minimizes effect of tooth mesh variations and assures uniform time delay action of a retard gear train for a camera shutter mechanism. In the Kodak Synchro-Rapid 800 shutter, two opposed permanent magnets are used to regulate the at-rest, shutter-set position of an escapement wheel which would otherwise be random to the extent of 50 or 60 degrees of rotation as a result of backlash in the three-stage driving gear train.

One magnet, circular in shape, is mounted to the escapement wheel and revolves with it; the other, a bar magnet, is fixed adjacent to the escapement wheel. In assembly of the gear train, the escapement wheel is mounted so that the polar location of the circular magnet allows greatest attraction or repulsion by the stationary magnet at the critical retard exposure time — 1/200 second in this case. Minimum variation in the amount of retard action is thus assured by the device which acts to maintain a constant initial operating phase relationship between the driving sector and the escapement.


Sector
Intermediate gears
Bar magnet
Magnetic disk
Esc. wheel
Retard pallet


Retard sector
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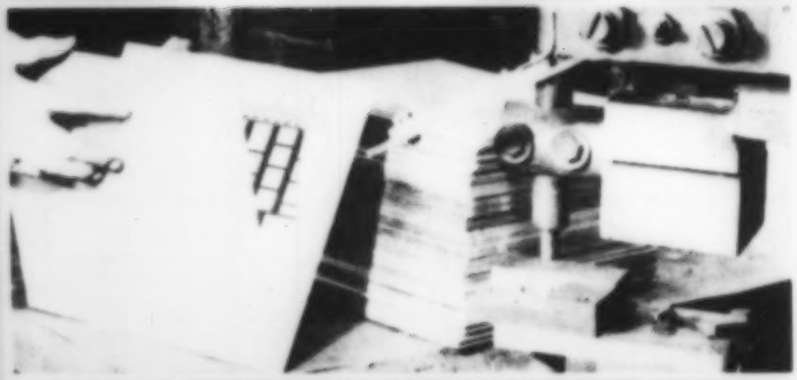
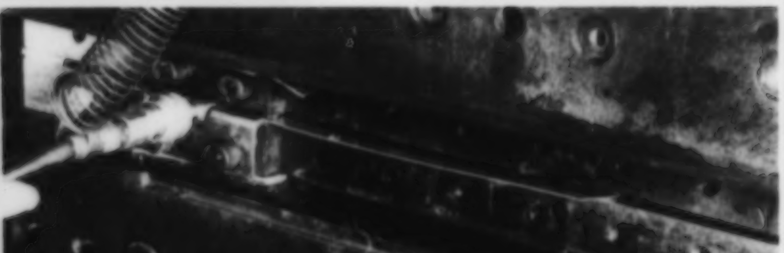
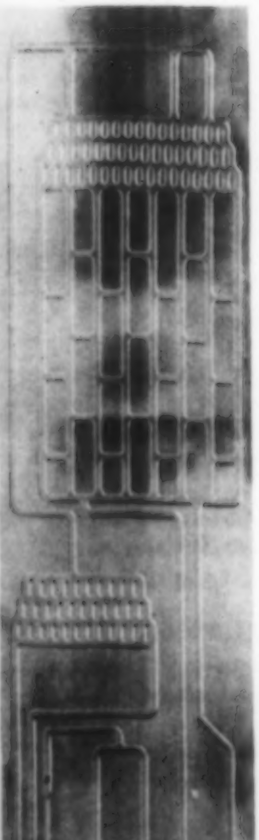
Escapement wheel
Retard pallet

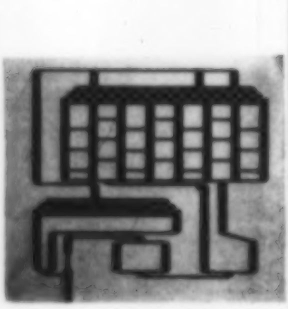




PRINTED FLUID CIRCUITS offer a new concept in design and fabrication of simple or complex tubing patterns for hydraulic and pneumatic applications. Conventional tube assembly techniques and associated hardware are eliminated through a process in which tube circuits, printed on a sheet of metal, are reproduced directly in three-dimensional form. Headers or accumulators can be readily incorporated in the circuit design and even complicated parallel or multiple tubes, running at right angles in two or more layers, can be produced.

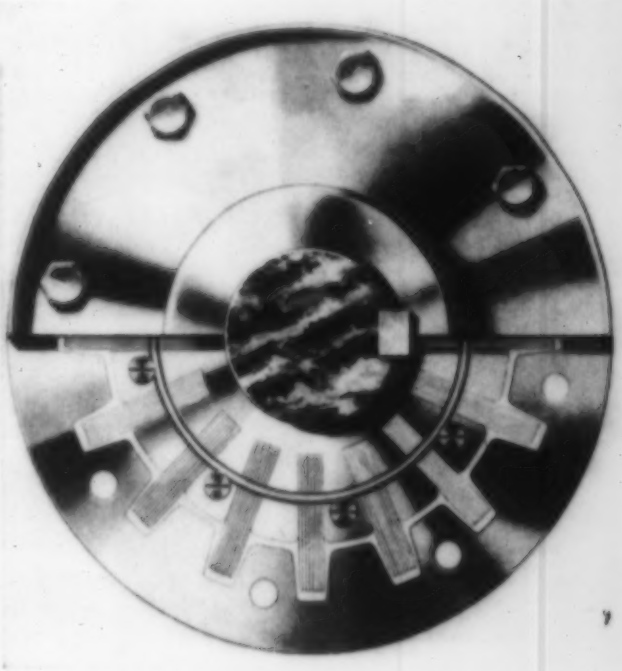
In the process developed by Olin Mathieson Chemical Corp., a silk-screened image of the tubing pattern, distorted to accommodate elongation, is applied to a sheet of aluminum or copper by means of a "stop-weld" paint compound. A second sheet is then placed over the pattern sheet and the metal sandwich is fused under heat and pressure, welding everything except at the pattern image, by a roll bonding technique. Subsequent cold rollings reduce the homogeneous sheet to proper thickness. After annealing and trimming, a needle is inserted at the lead-in end of the stop-weld pattern and the bonded plate is placed between two heavy platens. Hydraulic pressure is then applied through the needle, inflating the unbonded pattern areas to the height of the platens to form the preplanned tube circuit.

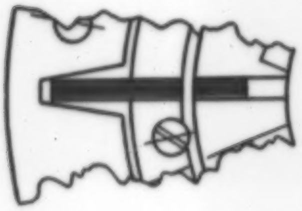


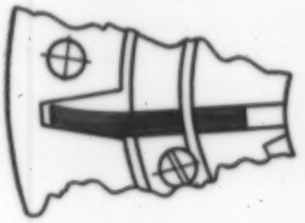


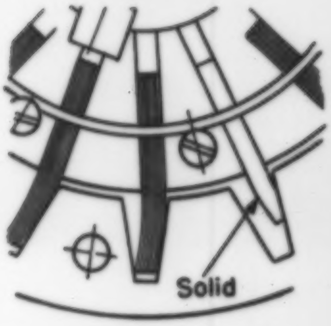
IDEAS

VARIABLE RESILIENCE to accommodate changing torque loads is achieved with cantilever springs in a flexible drive coupling designed by Brown Engineering Co. Mounted to one of the coupling drive members in the form of laminated radial spokes, the springs engage tapered slots in the other drive member to provide a positive power connection. In operation, resilience of the coupling changes automatically with load variations. As loads increase, the point of contact between the spring spoke and tapered slot moves inward due to spring deflection, shortening the effective spoke length and stiffening the drive connection. Two solid steel spokes which contact the tapered slots only during heavy overloads prevent excessive deflection of the springs. In addition, since the driving surfaces are parallel to the shaft, no end thrust can be developed and free end play is assured.

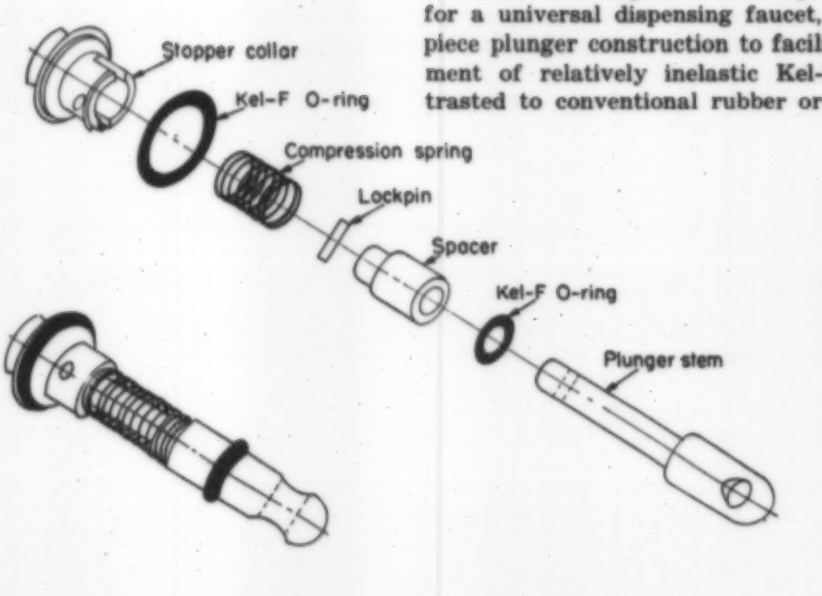


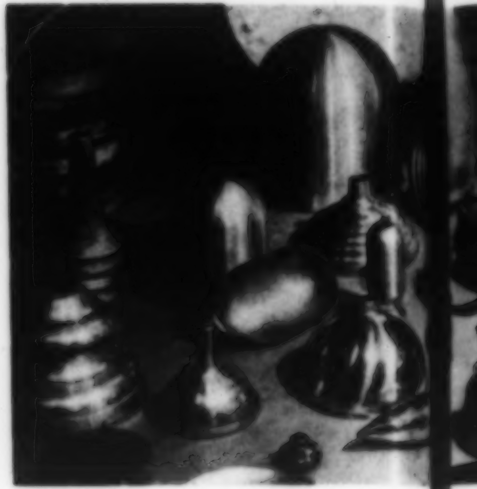






INELASTIC O-RINGS of plastic material are employed in a novel plunger design to permit operation in fluids harmful to rubber or neoprene. Developed by Economy Faucet Co. for a universal dispensing faucet, the design utilizes a five-piece plunger construction to facilitate assembly and replacement of relatively inelastic Kel-F O-rings which, as contrasted to conventional rubber or neoprene types, could not be expanded and slipped into position without splitting. Tightness of the assembly is maintained by a compression spring mounted between a spacer backing the O-ring and a locking collar. In operation, the chemical inertness and cold flow characteristics of Kel-F combine to provide an effective, sanitary seal resistant to corrosion, heat, fumes and microbiological growths.





Design Considerations for Spinforming

SPINFORMING has, for many years, been considered predominantly as a manual forming method, suitable for low-quantity production. A distinct advantage of the method is that a few special parts can usually be supplied quickly and at low initial cost. Reductions in cost are possible because tooling costs are less.

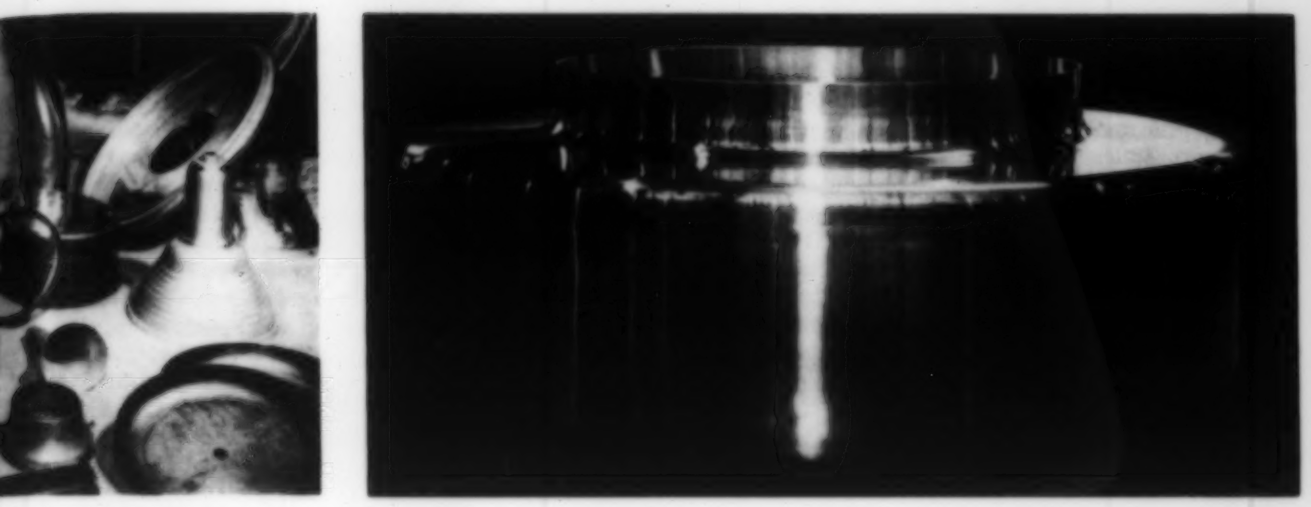
But machines are being developed which will permit larger quantities of spun parts to be produced rapidly and uniformly. In the future these machines will become more automatic. Principles common to other automatic machinery doubtlessly will find their place in spinforming. Such techniques as the programming of operation sequences and employing a pantograph linkage against a master template may become common practice. To be practical these machines will need to be designed to handle a wide variety of shapes and sizes without extensive modifications in tooling and setup. Machines using some or all of these techniques are already in existence for specialized applications. Such machines are designed to handle a limited variety of shapes and sizes. Newer machines now being developed are expected to handle a wider variety of shapes and sizes and to do so without extensive modification in tooling and set-up. When these newer facilities are more generally available, they could have great impact on spinning as a volume production method.

Spun parts may consist of circular or cylindrical pieces with reverse curves, narrow necks, concave and convex shapes, and beaded edges. They can be manufactured to precise dimensions and controlled wall thicknesses. Sizes of parts made by spinforming range from pieces as small as the end of a human finger to units twice the height of a man, *Fig.* 1. While spinforming can be applied to the forming of many basic metals, this article will be devoted to design considerations.

Cost Factors: When time is a crucial consideration, stainless parts are often spun without complete detail drawings. Essential features are sketched and dimensioned to the required accuracy, whereas radii, intermediate sections, precise contours, etc., are left to the discretion of the spinner. This approach is often advantageous in the fast pace of development and prototype model-making necessary for many designs.

Cost alone may be a determining factor if a part can be made equally well by spinforming or in a drawing press. As a rough general rule, tooling expense for spinning will come to only 10 to 15 per cent of the cost of tooling up a corresponding part for press work. This percentage would naturally depend on part complexity.

Usually when a part can be made by either method, very large quantities cost less if drawn while very small quantities cost less if spun. For each such part, then, obviously a "break-even quantity" that can be computed or estimated to determine which method will yield lower costs.



Stainless Steel

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However, the process of spinforming stainless steel should not be regarded as exclusively a short-run process. Also there are many shapes that cannot be made by other methods with anywhere near the same facility as by spinning.

Spinforming Shapes: Typical metal parts that are most ideal for spinforming are large dished or cylindrical pieces of relatively thin metal, elaborately shaped elements that are symmetrical about an axis of revolution, and composite assemblies that employ spun-over edges for mechanical joints.

A spinformed part will often require a tremendous deformation to make it from its blank. For example, bottle shapes with narrow necks are spun from flat stainless steel disks. The ideal applications though, are those which involve more modest working of the original blanks, *Fig.* 2.

Flat blanks can be spun into rather flat conical shapes most

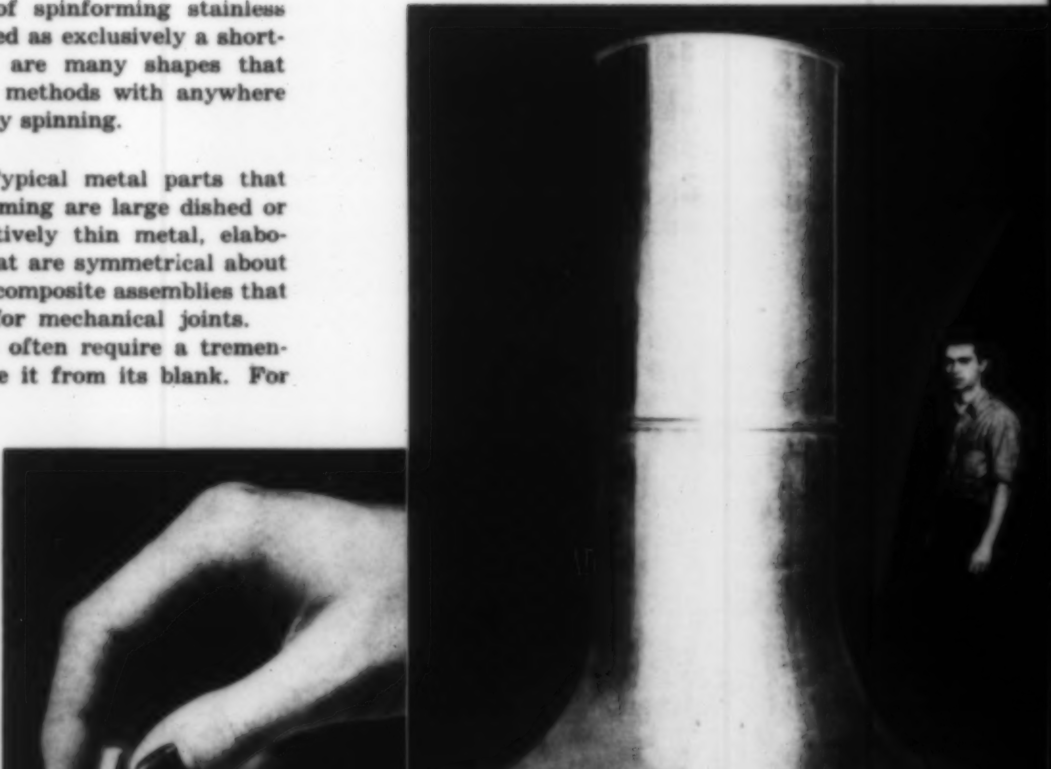


Fig. 1—Range of sizes of spun parts

easily, and the difficulty increases as the cone gets sharper, *Fig*. 3*a*. If the advantages justify it, a conical shape may be formed by welding together the ends of a circular-segment blank and spinning into final form in fewer breakdown steps by the procedure demonstrated in *Fig*. 3*b*. Flat blanks can be spun into bell shapes and cups, too, *Fig*. 4. Obviously, the deeper the part, the more work is required.

Tubular blanks, *Fig*. 5, can also be spun. Such blanks may be either thin-wall stainless tubing or may be welded up as required from sheet or strip.

These observations on shapes of blanks are significant in the determination of which are good spinforming applications, because they point up the versatility of the process. They emphasize that thinking should not be limited to the near-flat or simply-shaped stainless parts.

Size and Thickness Factors: The heaviest stainless stock generally handled by spinforming is 0.125-inch in thickness or, in some cases, 0.178-inch. Large disks can be accommodated in conventional horizontal or vertical lathes. Usually, stainless steel spinnings are limited to about 16 feet in overall diameter.

Limits on the small side go down to blank thicknesses in the range of 0.025-inch. Wall thickness of the final part may range down to 0.019 to 0.016-inch or less. Diameters of parts measuring ½-inch and less are not uncommon for spinforming.

Finish: Surface finish of a stainless blank is more or less destroyed when it is spun. Either corrosion resistance or good appearance usually influence the choice of stainless over other metals in the first place. Therefore, because a smooth surface is essential in either case, the task of finishing the part should be planned at the outset. While still on the spinning lathe, parts can be abrasive polished, buffed, satin-brushed, or given whatever surface sheen is desired. A highly polished stainless steel spinning is shown in *Fig*. 6.

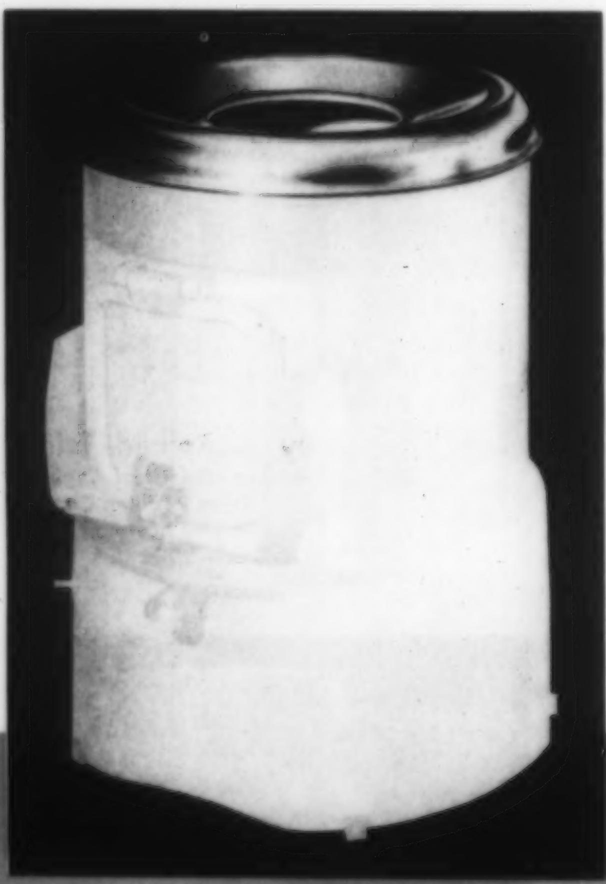
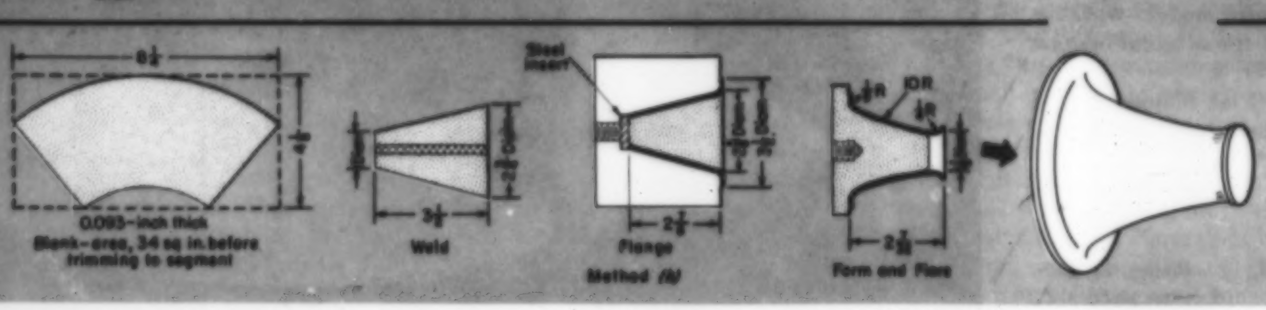


Fig. 2—Left—Potato peeler cover spun from 0.049-inch stainless steel

Fig. 3 — Below — Two methods of spinning flanged conical part employing type 437 stainless steel


0.093-inch thick
5½ Diam
Blank-area, 30 sq in. before trimming to circle
20°
First Breakdown
50°
Second Breakdown
70°
Third Breakdown
⅛R
10R
Flange
Trim and Flare
Method (a)
8½
0.093-inch thick
Blank-area, 34 sq in. before trimming to segment
Weld
Steel insert
Flange
Method (b)
Form and Flare

The spinformer does this as part of the overall job of producing parts to drawings and specifications.

Spinforming Design: Stainless steel can be spun into practically an unlimited variety of circular or cylindrical shapes and outlines. However, some of these features require extra work and some entail special tooling. There are a number of general considerations a designer should keep in mind when sizing up the possibilities of a spinformed stainless part.

Ordinary spinning jobs are performed on a chuck, except in some special cases. This rotating form, against which the metal is spun, acts as the mold or shape-determining element. Unless it is physically possible to make a chuck or series of chucks that will result in the desired shape, and unless the chuck can be separated from the part, the likelihood of successful spinning is remote. Sometimes, if a single stainless piece is needed, its chuck, made of wood, can be burned out. The chuck is, of course, destroyed. This "one-shot" expedient cannot be used with metals that soften or melt at temperatures of burning wood.

More than one chuck may be needed to produce a part if it has a beaded edge or a flange that would interfere with the first forming chuck. A "piece chuck" that comes apart in sections, *Fig.* 7, may be required if the part has a re-entrant flange or reduced bottleneck that prevents removal of a one-piece chuck. Such jobs are often handled in stainless steel but cost is more than with simpler spinnings.

How severely the steel will be worked is another factor that makes a design easy or difficult from a spinning standpoint. Here, the designer can get some idea of how big a problem he is presenting to his spinner if he asks, "How much will the diameter be changed at the extreme position?" Re-

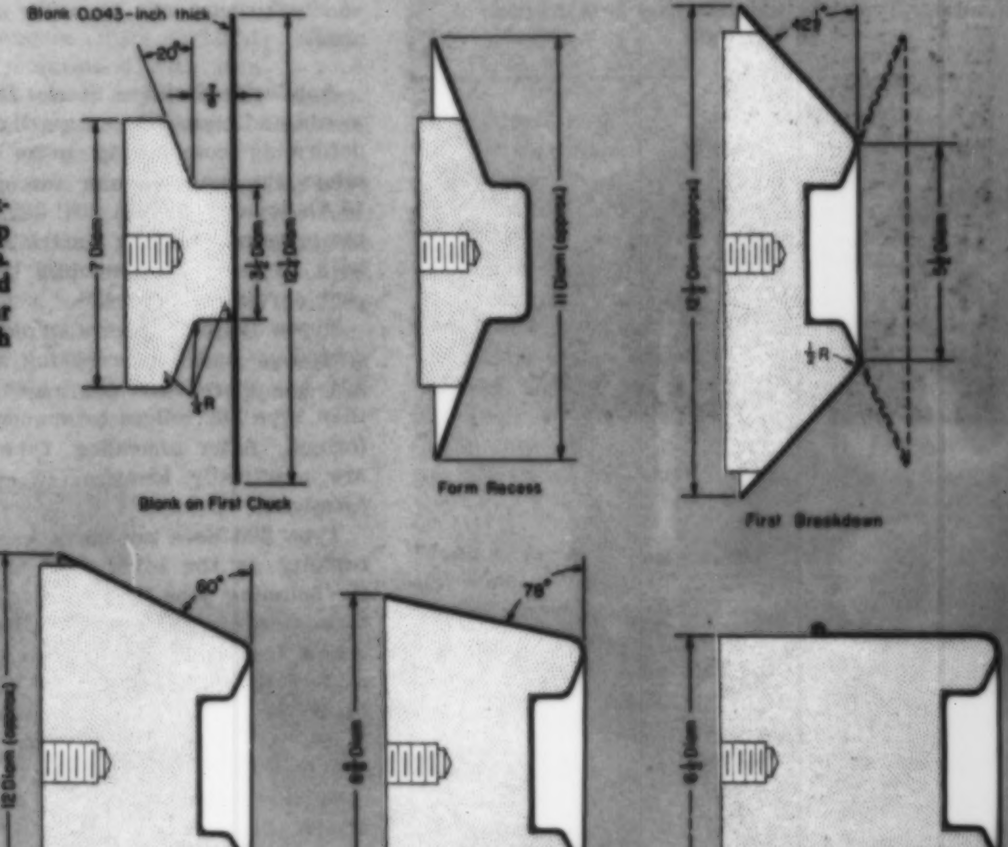


Fig. 4—Steps for making spun formed cup with recessed bottom. Type 302 annealed stainless steel circular blank is 0.043-inch thick

Blank on First Chuck

Form Recess

First Breakdown

Second Breakdown

Third Breakdown

Finish Form

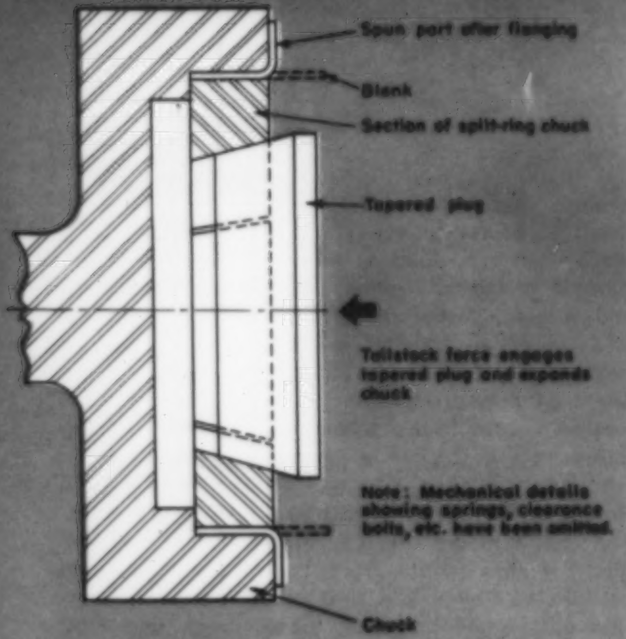
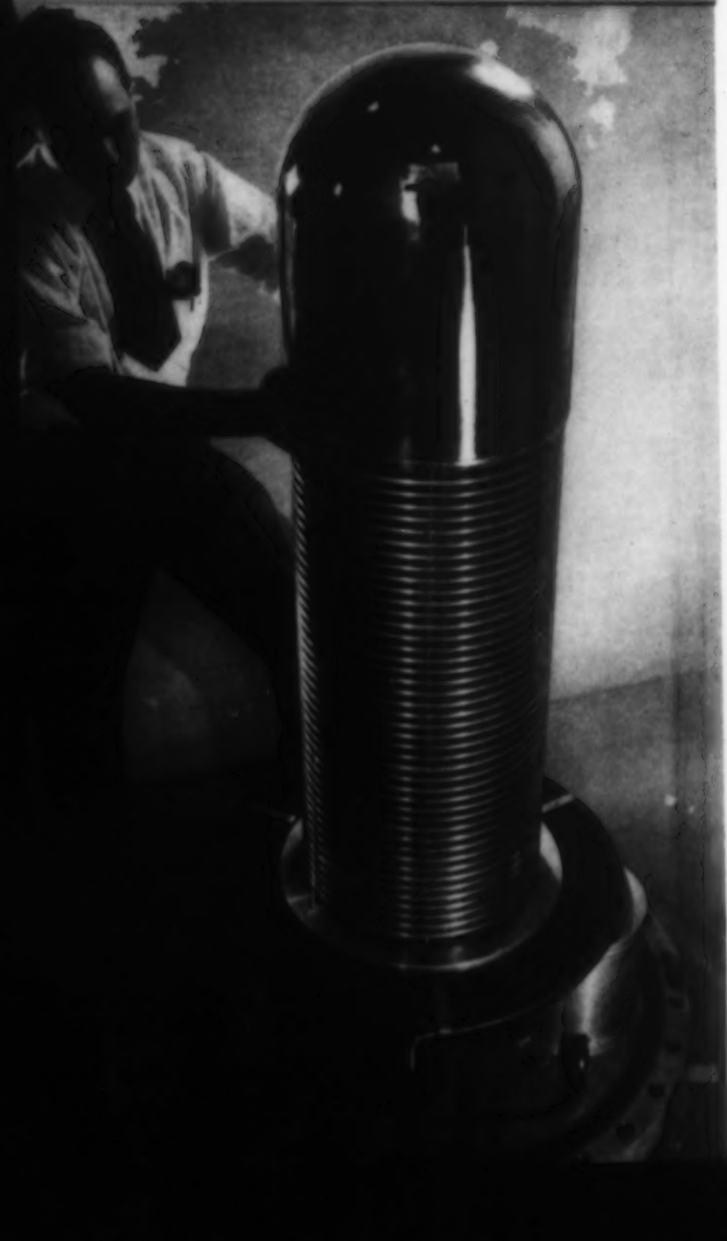

Spun part after flanging
Blank
Section of split-ring chuck
Tapered plug
Tailstock force engages tapered plug and expands chuck
Note: Mechanical details showing springs, clearance bolts, etc. have been omitted.
Chuck

Fig. 5 — Above — Expansion chuck spinning technique. Blank may be welded cylindrical ring or rolled-up strip

Fig. 6—Below — High-voltage terminal shell spinning. Type 321 stainless steel is 0.125-inch in thickness



duction to less than 60 per cent of original diameter or stretching to more than 140 per cent of original diameter will usually entail one or more extra annealing stages and possibly progressive chucks. Another question is, "How big are the changes of angle that the blank must undergo in order to conform to the chuck?" For example, it is easier to spin a cone with constant angles than it is to spin a hemisphere, *Fig*. 6, which involves angular changes varying from 0 to a full 90 degrees.

Sharp radii are not desirable in spinforming design, especially if close tolerances have to be held. For stainless steel, a good working minimum is five times blank thickness. However, sharper corners can always be spun if required. Also, rolled-edge beads with radii of 1 or 2 times the metal thickness are usually formed with special tools.

Tolerances vary with the size of the part, length of the dimension, type of measurement, etc. A good working tolerance for average dimensions is ±0.015-inch. Where necessary, ±0.010-inch can usually be held on a stainless-steel spunformed piece without much difficulty. However, anything much closer than this on any but the very small jobs will probably mean extra spinning operations and additional chucks with attendant cost penalties.

Applicable Stainless Steels: Both end-use requirements and tremendous capacity for stretching and deforming combine to make the 18-8 stainless alloys the most popular for spinforming. Of the 18-8 alloys, types 302, 304, 305, and 321 are among the principal spinning materials. Work is also done with 12 per cent chromium type 410 and 17 per cent chromium type 430.

Types 302 and 304 are employed for the average corrosion and heat-resisting applications. Type 304 has more corrosion resistance after welding than type 302 unless subsequent annealing is performed. After annealing, type 302 and type 304 are practically identical in properties and performance.

Type 305 does not work harden with the same rapidity as the other 18-8 alloys. This suits it for spinning jobs because a higher amount of deformation can be undergone before the metal becomes too hard and has to be annealed to preclude rupture. In fact, type 305 is often called a "spinning grade" of 18-8 stainless. It performs in service as well as the other 18-8 types.

Type 410 can be spinformed. Its ductility is less than that displayed by the chromium-nickel 18-8 alloys. However, it offers advantages in being hardenable by heat treatment and not being significantly work-hardenable. Parts can be spun to shape, then heat treated as required for hardness and high strength.

Type 430 is also less ductile than 18-8 and not very hardenable by cold working. It tends to stretch and deform locally when worked. This behavior, which may sometimes be objectionable for deep drawing, is ideal for spinning. Characteristics of type 430 stainless during spinning operations are much like those found in ordinary mild steel.

Tooling and Techniques: The first item of tooling for a new spun part is a chuck on which to form the blank. Often this is the only tooling item required. Sometimes, of course, several chucks have to be made because the forming is too complex to be accomplished in one stage. Sometimes a collapsible chuck is needed—one that comes out of the part piece by piece. Choices and design details of chucks are not of general concern to designer, however. These matters are a specialty of skilled spinning craftsmen.

Chuck materials are chosen with regard to length of run, blank thickness, and tolerance requirements. For stainless steel, most production spinforming is done on cast iron or steel chucks. Experimental or development work—spinning a few prototype parts when delivery time is short and tool cost an important factor—may suggest the use of a maple chuck or form. Although wood is hard and durable enough for thin stainless steel or for most thicknesses of soft metals, heavier stainless steel—say, 0.109-inch and up—will usually call for iron or steel tooling. Occasionally a metal working surface is added to the wood chuck by spinning it on to increase chuck durability. Closer tolerances can be maintained with iron or steel tooling. For this reason, if a job requires several operations on a succession of chucks, the final finish form may be of metal.

Hot spinforming solves some problems involving extreme deformations. In this technique the blank is heated with a torch flame while it is in the lathe and being worked. The alternative, of course, is to remove the part for annealing and pickling between successive operations. Hence, the application of heat will tend to reduce the cost of producing severely deformed pieces. Approximate temperatures for hot spinforming stainless are:

1. Type 410—1600 F
2. Type 430—200 to 1600 F
3. Type 302—1950 F
4. Type 304—1950 F
5. Type 305—1950 F
6. Type 321—1800 F

The foregoing data are based on current spinning practice and on limitations that will keep costs fairly well in line for today's techniques.

Developments are being pushed to permit more automatic spinning and to increase greatly the thickness of stainless steel that can be spun. Control of heavy tool forces will make it possible to work heavy plate.

A rather remarkable corollary will be the ability to thin down metal stock to a fraction of original blank thickness. By arranging two or more tools around the periphery of the work, it is possible to balance out the tremendous forces involved. Then, with proper tooling, a stainless plate can be "ironed" against a chuck so that it becomes a thin, formed sheet. This process involved severe "flow" or internal shear of the metal. Long cylinders with heavy ends and thin walls, produced experimentally in stainless by this process, bear a rough resemblance to parts made in softer metals by impact extrusion.

One fundamental reason why spinforming is to be increasingly important in stainless steel fabrication may be mentioned here. As a high-strength material, stainless requires exceptionally heavy, rigid machine tools and dies whatever the forming operation is. Spinning localizes metal flow at any one time to the area immediately adjacent to the tool. Thus, force and power to accomplish a given severity of forming are smaller for spinning stainless steel than for other forming methods.

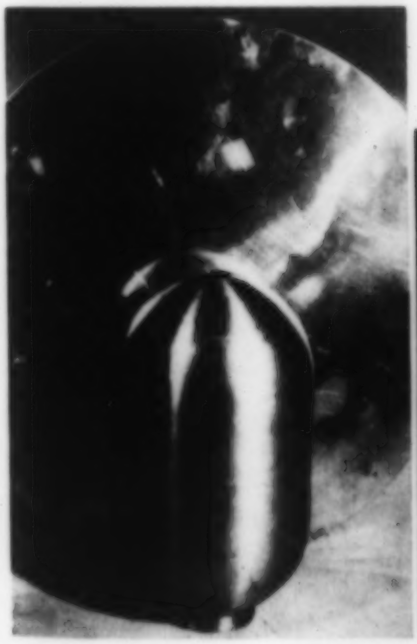
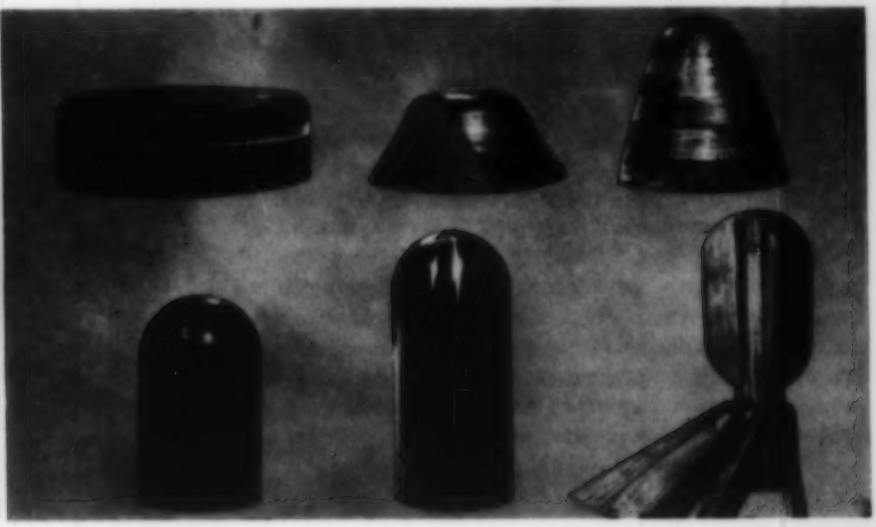


Fig. 7—Wooden forms for producing Greer accumulator. Final form is collapsible chuck



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PRECISION GEARING

New methods of design analysis have evolved to meet the performance requirements of gearing for control applications. Objectives of these methods are the regulation or elimination of backlash and control of inaccuracy such as errors in angular position and velocity ratio. How to appraise and control backlash and inaccuracy sources, and how to encompass these aspects in design are the objectives of this series of articles.

CONTINUAL growth and expansion of the fields of automatic control and computation have led to increasingly severe demands upon gear-train performance. Many mechanical and electromechanical servo loops are being designed to accuracies and performances which require extreme-precision gearing. In fact, in many electromechanical servo control circuits, the gearing is the limit to overall system accuracy and performance. Therefore, mechanical design is faced with the necessity of practically providing improved gear function.

There are two fundamental malfunctions of gears of serious concern in the design of a precision gear train: backlash and inaccuracy. Backlash is defined generally as lost motion, which can occur because of a multitude of reasons to be discussed. Inaccuracy is independent of backlash and relates to the variation of velocity ratio with rotation of the gears. Both have troublesome effects in precision gear trains. Excessive backlash causes poor response and hunting of servo systems, and inaccuracy will result in positional errors. This series of articles will review and analyze both with respect to their effect, sources, control, elimination and prediction of magnitude. The analysis of backlash will be presented first.

Much of the information will be of a general nature, although emphasis will be placed upon relatively small fine-pitch instrument gearing.

Backlash is defined as the amount by which the width of a tooth space exceeds the thickness of the engaging tooth measured on the pitch circle. Equivalent definitions would be the amount of motion a meshed gear has when its mating gear is held fixed; or the shortest distance between non-driving tooth surfaces of adjacent mating teeth.

These definitions imply that backlash can be expressed as either a linear figure, measured along the pitch circle or along the line of action, or an angular value measured at the gear center. Note that angular backlash must be referred to a specified gear or shaft of the meshed pair, because

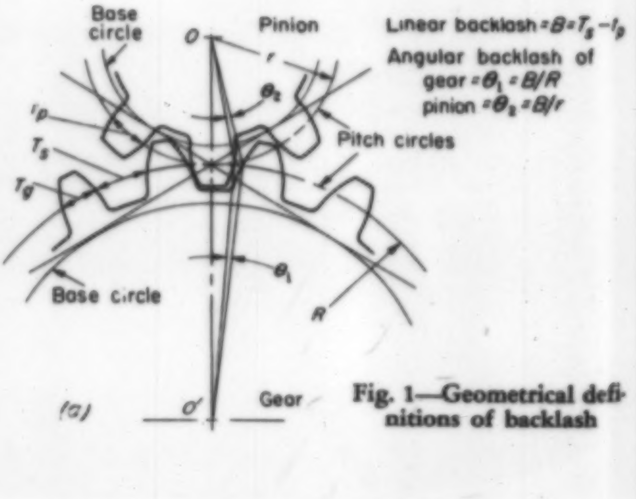

Fig. 1—Geometrical definitions of backlash

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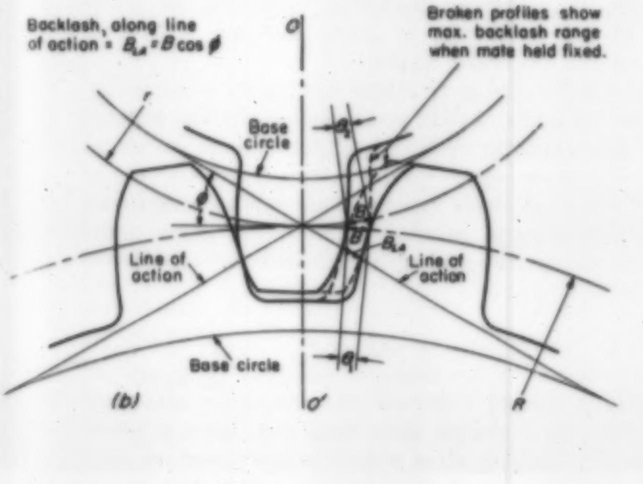
Part 1—Backlash Sources and Their Evaluation

angular values for each gear of the pair will vary as the velocity ratio. The geometrical relationships of backlash are shown in *Fig.* 1.

Theoretically, meshing gears do not have any backlash nor do they need any to operate satisfactorily. However, very necessary manufacturing tolerances on gear dimensions, shaft center location, and shaft and bearing dimensions result in backlash. Fortunately, this is not detrimental to conjugate gear operation, and in many applications it is actually beneficial since it provides space for lubricant and differential expansion due to temperature changes.

In some applications, particularly many within the field of instrumentation, backlash is objectionable and great effort is expended to eliminate or minimize its effect. A thorough understanding of backlash sources and methods of control combined with an understanding of manufacturing techniques enables the prediction of reliable backlash figures for specific gear train designs before they are actually made.

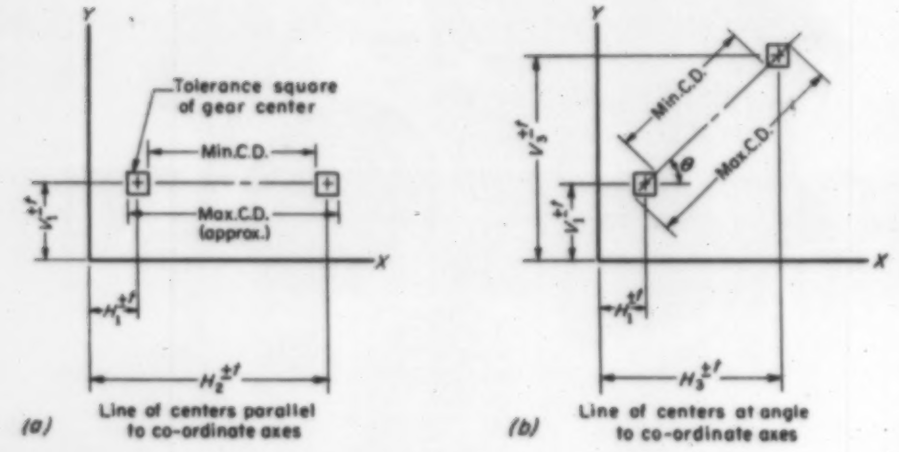

Backlash, along line of action = $B_{LA} = B \cos \phi$
Broken profiles show max. backlash range when mate held fixed.
O
Base circle
B_t
ϕ
B
B_{LA}
Line of action
Line of action
Base circle
q
(b)
O'
R

Backlash sources are numerous; they include the following:

1. Gear center-distance variation
2. Gear size
3. Pitch diameter runout
4. Ball bearing errors
5. Gear assembly to shaft
6. Shaft runout
7. Looseness of shaft, bearing, and housing bore
8. Composite gears
9. Environmental sources
10. Rigidity of installation

Each of these influences warrants discussion.

Gear center distance variation is usually the largest backlash component. Nominal gear centers are only theoretically possible since in practice the center distances will vary slightly from theoretical values regardless of the boring method employed. The tolerance on the variation depends upon the method of fabrication, i.e., jig boring machines, jigs and fixtures, templates, etc. To avoid gear interference, the tolerance on gear center distances is almost universally taken as theoretical nominal to plus some specified allowance. This means the


Y
X
Tolerance square of gear center
Min.C.D.
Max.C.D. (approx.)
$V_1^{\pm t}$
$H_1^{\pm t}$
$H_2^{\pm t}$
Min.C.D.
Max.C.D.
θ
$V_3^{\pm t}$
$H_3^{\pm t}$

(a) Line of centers parallel to co-ordinate axes

(b) Line of centers at angle to co-ordinate axes

Fig. 2 — Effect of orientation of line of centers on the spread between minimum and maximum center distance when co-ordinate dimensioning is used

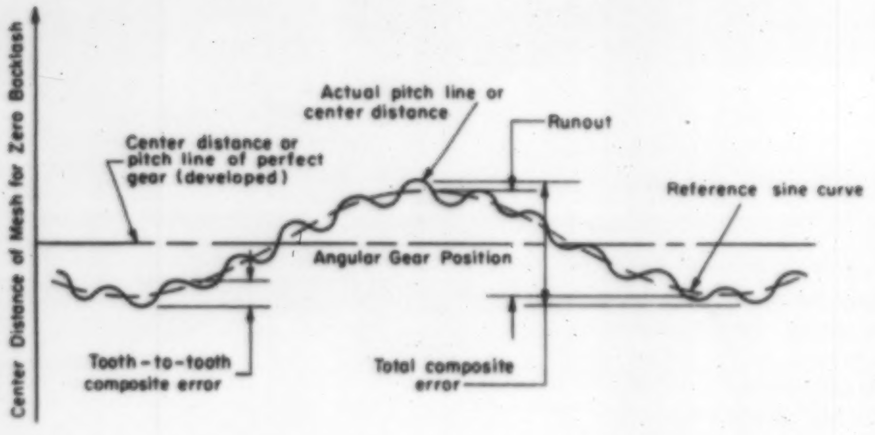

Center Distance of Mesh for Zero Backlash
Actual pitch line or center distance
Runout
Center distance or pitch line of perfect gear (developed)
Reference sine curve
Angular Gear Position
Tooth-to-tooth composite error
Total composite error

Fig. 3 — Developed plot of actual pitch line of gear as would be obtained from rolling with a master rack or gear on a variable-center-distance test fixture

gear centers at best will be just nominal, but more probably will be enlarged.

Considering gear center co-ordinates up to the order of five inches, practical limiting tolerances for various boring methods are as follows:

Jig boring	±0.0003-inch
Jigs and fixtures	±0.001
Special production techniques	±0.0005

These limiting tolerances can be bettered under certain conditions, but only with extreme care. Therefore, specifying closer tolerances must be soundly justified.

On gear housing drawings, the distance between gear centers is sometimes dimensioned directly, in which case the above tolerances would be directly applicable. For co-ordinate dimensioning of gear centers to the above tolerances, the spread of gear centers will vary with the slope of a line connecting the two centers. Centers in-line and parallel to either the X or Y-axis will vary as the co-ordinate tolerance. However, centers on lines at an angle to the co-ordinate axes will vary by the tolerance divided by the cosine of the angle. The geometry of this condition is illustrated in *Fig.* 2.

For gear trains having a string of centers, the gear center openings due to tolerances are interrelated. If one pair is at a maximum, the adjacent next pair cannot be at their maximum. In making backlash calculations consideration of this effect must be taken into account.

The relationship between center distance opening and backlash is a function of the operating pressure angle and can be readily derived by application of involute geometry fundamentals. The relationship is

$$B = 2\,(\Delta C)\,\tan\phi \qquad (1)$$

where B = linear backlash measured on pitch circle, ΔC = change in center distance, and ϕ = operating pressure angle.

In addition to gear center distances varying due to manufacturing tolerances, sometimes the centers are intentionally opened a slight amount to avoid interferences which could result from tolerances or from pitch circle runout. This can be considered a precautionary measure. The result is an additional source of backlash which must be considered in any analysis.

Gear size usually is one of the larger backlash components. It is common practice to speak of a gear as having a certain pitch diameter, although actually an involute gear does not have a pitch diameter until meshed with another gear on specific centers, or is engaged with a rack. For instance, if the center distance of two mating gears would be slightly altered, which could be the consequence of a manufacturing tolerance on center distance boring, the gears would operate on different pitch circles. Thus, the actual pitch diameter is an indefinite quantity until the centers are fixed.

However, for convenience, it is proper to speak of a nominal pitch diameter which is defined as the number of teeth divided by the diametral pitch. This would be the actual pitch circle size for theoretically perfectly made gears operating on exact nominal center distances. Furthermore, if these theoretically perfect gears meshing on nominal centers were assumed to have no backlash, their tooth thickness as measured on the pitch circles would represent a perfect, full-sized gear, and the tooth thickness would be one-half the circular pitch for standard gears, or $\pi/2P_d$ where P_d = diametral pitch. Tooth thicknesses of actual gears, measured on the theoretical nominal pitch diameter, can be larger or smaller than the perfect or ideal tooth thickness. This is accomplished during the manufacturing process by advancing the generating cutter a less or greater amount than nominal into the gear blank. It is common practice to slightly thin the teeth below the tooth thickness of a nominally perfect gear. Then, if the gear is operated on nominal centers (or larger, due to tolerances of center boring), there will have been introduced a small amount of backlash.

Table 1—Standard Specified Backlash*

Diametral Pitch	Backlash† (inches)
Class A	
20 to 45	0.004 to 0.006
46 to 70	0.003 to 0.005
71 to 90	0.002 to 0.0035
Class B	
20 to 60	0.002 to 0.004
61 to 120	0.0015 to 0.003
121 and finer	0.001 to 0.002
Class C	
20 to 60	0.001 to 0.002
61 to 120	0.0007 to 0.0015
121 and finer	0.0005 to 0.001
Class D	
Any pitch	No measurable backlash

*From AGMA Standard 236.03.

†Between two assembled gears at their tightest point of mesh. Backlash will be increased when the low points of runout are in contact.

Table 2—Backlash Components Converted from Table 1

Diametral Pitch	Intentional Backlash (in. per pair)	Backlash Tolerance (in. per pair)	Probability Factor for Tolerance
Class A			
20 to 45	0.004	0.002	0.5
46 to 70	0.003	0.002	0.5
71 to 90	0.002	0.0015	0.7
Class B			
20 to 60	0.002	0.002	0.5
61 to 120	0.0015	0.0015	0.6
121 and finer	0.001	0.001	0.8
Class C			
20 to 60	0.001	0.001	0.8
61 to 120	0.0007	0.0008	1.0
121 and finer	0.0005	0.0005	1.0

The relationship between tooth thickness and backlash is a linear function. The amount of backlash is equal to the amount of tooth thinning, since by definition both are measured along the pitch circle.

Tooth thickness or equivalent backlash can be readily determined by use of a variable center distance inspection fixture rather than by measuring the tooth thickness directly. This is particularly so in the case of fine and medium-pitch gears, but not applicable to large bulky power gearing. In this method the gear is rolled in mesh with a master gear or rack with the gear on floating centers, spring-loaded to close the mesh. The center distance of their operation depends upon the tooth thickness of the test gear, since the spring loading will force the teeth together until there is metal to metal contact. The exact center distance of operation is noted and compared to the theoretical nominal center distance, and any difference indirectly denotes backlash if the distance is less than nominal. Actual backlash can be obtained with Equation 1.

Therefore, it is obvious that control of the gear tooth thickness is important if operating backlash is to be controlled. The control resolves into two aspects: the amount of desired or design back-

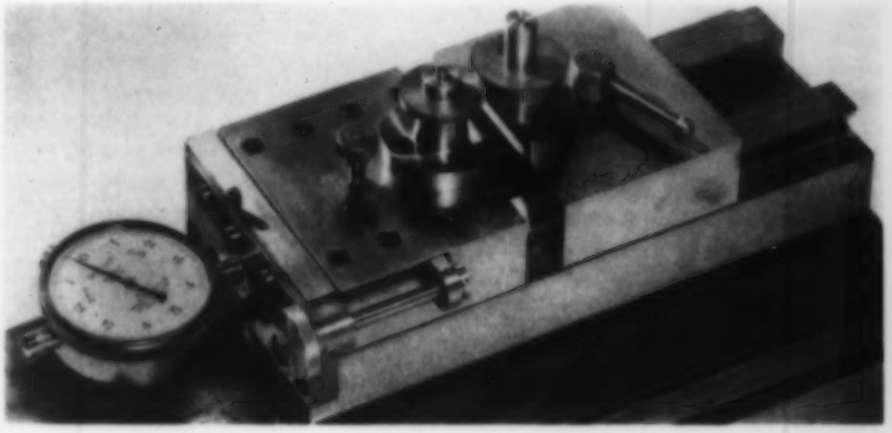


Fig. 4 — A manual variable-center-distance inspection fixture used for measuring total composite error, and the component errors: runout and tooth-to-tooth composite errors

lash and the tolerance for manufacture. Gears are sometimes made to the theoretical nominal tooth thickness, plus nothing to minus some specific tolerance amount. For such gears, the centers are usually opened by a small amount (0.001 or 0.002 inch), to avoid possible interferences. Gears are never made over nominal tooth thickness except for special cases. In the American Gear Manufacturers' Association fine-pitch standards, the gear teeth are intentionally thinned to provide specified amounts of backlash. In addition, the tolerance of manufacture allows the teeth to be still thinner, which is equivalent to additional backlash.

AGMA specification of backlash and tolerances for various classes of fine pitches are listed in *Table* 1. In *Table* 2 the AGMA data has been divided into components of minimum or intentional backlash and gear size tolerance which results in additional backlash.

Pitch diameter runout is usually present. It is nearly impossible to generate a gear without having the pitch circle vary slightly and have some eccentricity between the pitch circle and the bore. This usage of the term *pitch circle* denotes the circumferential trace through the gear teeth designating constant tooth thickness. Only for a theoretically perfect gear would this trace be a circle centered on the gear bore. In practice, this constant tooth thickness trace becomes slightly eccentric relative to the bore center and also departs from being perfectly circular due to tooth to tooth variations.

Obviously, the existence of any eccentricity will cause the gear teeth to work slightly in and out of mesh as the gear is rotated. Thus, the backlash will be increased as the short radius portion of the gear passes through the mesh point where the thinner outer portions of the gear teeth are in contact. Also, inherent generating errors such as tooth thickness variation, profile error, tooth spacing variation and lateral gear runout will cause additional backlash variation.

Table 3—Total and Tooth-to-Tooth Composite Error Limits*

Class	Total Composite Error (in.)	Tooth-to-Tooth Composite Error (in.)	Probability Factor for TCE
Commercial 1	0.006	0.002	1/2
Commercial 2	0.004	0.0015	1/2
Commercial 3	0.002	0.001	2/3
Commercial 4	0.0015	0.0007	2/3
Precision 1	0.001	0.0004	2/3
Precision 2	0.0005	0.0003	0.8
Precision 3	0.00025	0.0002	1

*From AGMA 236.03. For spur, helical, worm and bevel gearing.

Table 4—Ball Bearing Runout*

ABEC Class	Inner Race Eccentricity (in. TIR)	Outer Race Eccentricity (in. TIR)	Probability Factor
1	0.0003	0.0006	1
3	0.0002	0.0004	1
5	0.0002	0.0002	1
7	0.0001	0.0002	1

*For bores to ¼-inch only.

These errors plus pitch circle runout are also very important in regard to the accuracy of instantaneous velocity ratio or position accuracy of gears. This important effect will be analyzed further in a subsequent article in this series. For the present discussion, only the backlash effect will be considered.

A plot showing the deviations of the pitch circle would appear as shown in *Fig*. 3. This plot shows tooth to tooth variations superposed upon the runout due to bore eccentricity. It is conventional to measure the overall variation which is termed total composite error. This criterion must be specified for complete gear design. As a guide, *Table* 3 lists the various classes of AGMA gears and the ranges of total composite error.

The total composite error curve is obtainable for fine pitch gears by any one of several conventional methods. The curve of *Fig*. 3 can be directly derived by meshing the gear with either a master inspection rack or gear, whose similar errors are negligible, on a spring-loaded floating center such that intimate metal to metal contact exists and there is then zero backlash. Then, the indication of instantaneous center distance will yield the plot of *Fig*. 3. One type of small manual variable-center-distance inspection fixture employing master gears is shown in *Fig*. 4.

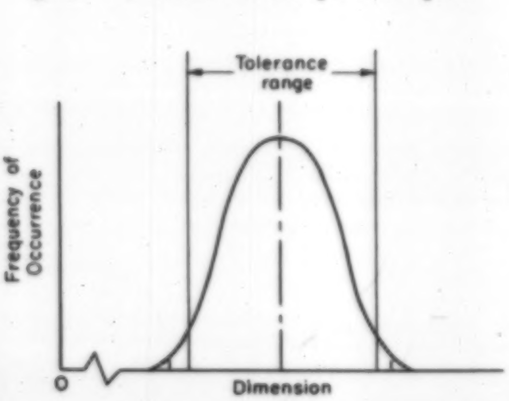
From the geometry of contacting involute teeth, the linear backlash for each gear will be increased at the low point by the following amount:

$$(\Delta B)_{max} = e_T \tan \phi \qquad (2)$$

where $(\Delta B)_{max}$ = maximum increase of backlash and e_T = total composite error.

Note the backlash due to total composite error

Fig. 5—An ideal typical Gausian distribution curve for the variation of a given dimension from part to part



is a component which continually varies with gear rotation. Equation 2 gives its maximum value.

Ball bearing errors affect the backlash of meshed gears. For a rotating inner race, any runout of the inner race will cause the center of a gear mounted to a shaft in the bearing to have a small circular motion. In effect the pitch circle is given an added component of eccentricity, introducing a variable amount of backlash as a function of gear rotation. Thus, this backlash source is similar to pitch diameter runout.

The eccentricity of the outer race has a different effect. If the outer race is fixed, and any eccentricity will result in a permanent shift of the gear center. However, this shift can occur in any direction, resulting in opening or closing of the gear centers, the exact amount depending upon the angular orientation of the shift. This type of center shift is also true of pressed-in bearing bushings having any runout between the outside and inside diameters.

Eccentricities of inner and outer races for various ABEC classes of ball bearings are listed in *Table* 4. The runout figures are extremely small; usually this source has little effect on the total backlash of a mesh.

In addition, radial play in ball bearings, especially if excessive, can add to the backlash. This is particularly true of highly loaded meshes which will have their centers forced apart to the fullest amount. However, for many instrument applications, the loads are light and the ball bearing play is in the order of 0.0002 to 0.0005-inch, which contributes only a small amount of backlash.

Table 5—Clearance Between Shaft and Gear

AGMA Class	Nominal Shaft Diam. (in.)	Nominal Gear Bore* (in.)	Maximum Clearance (in.)	Maximum Gear Center Shift (in.)	Probability Factor
Commercial 1	+ 0.0001 −0.0002	+ 0.0021 + 0.0001	0.0023	±0.0012	1/2
Commercial 2	+ 0.0001 −0.0002	+ 0.0011 + 0.0001	0.0013	±0.0006	1/2
Commercial 3	+ 0.0001 −0.0002	+ 0.0008 + 0.0001	0.0010	±0.0005	2/3
Commercial 4	+ 0.0001 −0.0002	+ 0.0008 + 0.0001	0.0010	±0.0005	2/3
Precision 1	+ 0.0000 −0.0002	+ 0.0006 + 0.0001	0.0008	±0.0004	2/3
Precision 2	+ 0.0000 −0.0002	+ 0.0003 + 0.0001	0.0005	±0.00025	3/4
Precision 3	+ 0.0000 −0.0002	+ 0.0003 + 0.0001	0.0005	±0.00025	3/4

*Plus (+) for both values is to be interpreted as an increase of the nominal by the smaller figure of the two with a plus tolerance equal to their difference and a zero minus tolerance. For example, a Precision 1 bore would be (Nominal +0.0001) +0.0005, −zero.

Table 6—Shaft Runout for Typical Components

Component	Maximum TIR at Shaft End (in.)	Probability Factor
Precision synchros	0.001	0.7
Precision resolvers	0.0002	1.0
Precision potentiometers	0.0005	0.8
Stepped shafts		
Lathe-turned shoulders	0.001	0.8
Precision-turned shoulders	0.0005	1.0
Precision-ground shoulders	0.0002	1.0
Precision centerless-ground shafting	0.0001 (per inch of length)	1.0

Gear assembly to shaft is a source of backlash which, in extreme cases, can be appreciable. It is due to the clearance which exists between the gear bore and shaft mounting diameter, or whatever mounting means is used. Regardless of the method of fastening, whether clamped, staked, or pinned, it is probable that if there is any clearance, the result will be an eccentric assembly. The effect will be runout of the pitch circle resulting in backlash variation with rotation. As an example, *Table* 5 lists shafts and bore dimensions, tolerances, and maximum clearances for the various AGMA gear classes. For precision gearing the effect is small.

This backlash source can be essentially eliminated if the clearance is reduced to zero by specifying a press fit, but the pressing must be done properly.

Shaft runout, measured between the bearing diameters and the gear mounting diameters, further affects backlash. Shafts, especially if long and slender, and/or if the bearings are stepped will have a noticeable amount of runout. The effect on backlash will be a cyclic variation with shaft rotation.

Examples of runout values for machined parts and components encountered in precision gearing are listed in *Table* 6 which also reveals the majority to be merely small backlash sources.

Looseness of shaft, bearing and housing bore may result from imperfect fits between the shaft and inside diameter of the bearing, and the outside diameter of the bearing and the housing bore. For ease of assembly, there may be an intentional looseness. Also, manufacturing tolerances on the mating diameters will allow an increase of this looseness. Thus, when the gears transmit load, the tooth reactions force the gear centers apart. Fortunately, the effect is diminished since the pressure line makes an appreciable angle with the line of centers. The result is that the center distance is increased by one half the magnitude of the diametral looseness times the sine of the pressure angle. For precision assemblies looseness is usually a very small source, and is important only when the allowances are considerable and the bearing loads high.

Composite gears consisting of an assembly of gear and hub have an additional backlash component due to the eccentricity of the assembly. Also, if there is clearance in the assembly fit, still more backlash will be introduced.

Environmental sources include situations where gear trains are required to operate throughout a range of ambient temperature. They are then subject to dimensional variations due to the coefficient of linear expansion, and backlash can be affected. If the materials of the gears, shafts and housings are the same, there will be no noticeable effect on backlash. However, if the gear and housing materials have widely different coefficients of expansion, the effect on backlash can be significant if the temperature range is large.

Rigidity of installation is a final possible source of backlash. Long, slender shafts will both deflect as a beam and twist torsionally; similarly, the bearing loads will cause housing deflections. Structural design may often at first glance seem adequate; however, more careful scrutiny may often show that this source should not be overlooked.

Evaluation of backlash sources as well as their relative importance is of value because of their number and extent. For convenience most of these sources can be classified, *Table* 7. Environmental and rigidity sources have been omitted because they are not normally encountered.

Group A is of basic importance because these sources are design values of backlash, subject only to the desires of the designer. Once their values have been established, they result in a known amount of backlash. The total backlash of this group is the ultimate minimum backlash that can possibly be achieved for the mesh, and could only exist if all other remaining backlash sources were reduced to zero.

Table 7—Classification of Backlash Sources

Group A—Design Components
1. Any specific increase in center distance above nominal
2. Reduction of gear size (tooth thickness) from nominal

Group B—Allowance or Tolerance Components
1. Tolerance on gear size (tooth thickness)
2. Center distance tolerance
3. Bearing center shift
   a. Outer race eccentricity of ball bearings
   b. Runout of ID and OD of sleeve bearings
4. Radial clearance in bearings
5. Tolerances on shaft diameter, bearing diameters and housing bearing bore diameter

Group C—Components Variable with Gear Rotation
1. Total composite error of pitch circle
2. Clearance fit between gear bore and shaft
3. Shaft runout at point of gear mounting
4. Ball bearing inner race eccentricity
5. Composite gears
   a. Eccentricity of gear mounting surface and hub bore
   b. Clearance between gear bore and mounting surface

The sum totals of backlash components of Group B are usually the most important. The gear size and center distance tolerances are usually of such magnitude as to contribute major backlash components. The bearing errors are small and can be often neglected. The most important aspect of this component group is that their absolute backlash values cannot be assessed. This is obvious, since a tolerance is an engineering legality to allow dimensional variation. This results in each backlash component having a possible value from zero to some maximum amount. However, by methods to be explained, it is possible to predict probable backlash values for this group.

Group C is similarly difficult to establish with fixed absolute values, since the magnitude of runout and eccentricities is only controlled within certain limits, and their exact values are unspecified and will vary from unit to unit. Further, the exact backlash contribution of each component is more confused by the value of the relative angular phasings among the components.

Thus, to the designer, backlash sources of Group A are completely controlled, but those of Groups B and C are of more concern since they are controlled only as to maximum values.

Integration of backlash components can be performed for any designed gear train to obtain an idea of the magnitude of expected backlash by analyzing all of the listed backlash components. This requires complete knowledge of all design criteria as well as knowledge and understanding of the various manufacturing tolerances and techniques employed.

Obviously, an overall, maximum backlash figure can be obtained by assuming the most unfavorable tolerance conditions and where angular phasing is a factor (Group C in *Table* 7) assume complete

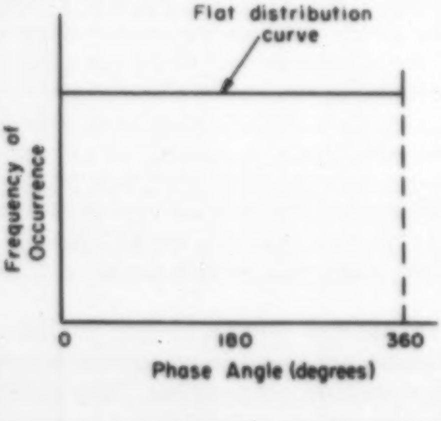


Fig. 6—Extreme left—Distribution curve for phasing angles of backlash components variable with rotation

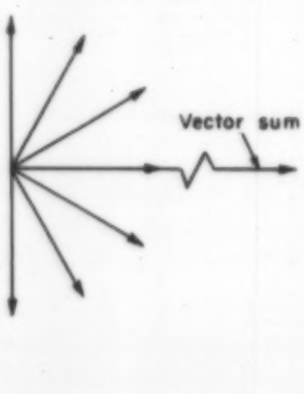


Fig. 7—Left—A flat distribution vector diagram for an assumed 180-degree additive phasing spread of eccentricity type backlash components. Magnitudes are assumed equal

additive phasing. Such a computation would produce a maximum extreme backlash figure which can be approached but is highly improbable. A much more useful result would be a probable backlash value.

Distribution curves of the various critical dimensions affecting the value of backlash components must be analyzed as the first step towards obtaining a probable backlash figure. For instance, the specified gear size tolerance establishes the minimum and maximum backlash contributions of this critical dimensional backlash source. Any particular gear will have a size which must fall somewhere between these two extremes. Exactly what it is depends upon a number of factors including machine setting, cutter condition, human error, etc. However, if inspection were made of a quantity of gears, a distribution curve could be plotted showing the relation between quantity and gear size. Usually, such curves are not flat, but peaked, resembling a Gausian natural distribution. *Fig.* 5 shows such a distribution curve. The gear train analyzer is confronted with the problem of choosing the probable value from the distribution curve. This is not difficult providing a distribution curve exists. Unfortunately, distribution curves are often not available. Then a probable value must be estimated from an appreciation and understanding of the fabrication tolerances, the technique, tools and machinery used to produce gears and associated parts. As a suggestion of magnitude, *Tables* 2 through 6 list in their last columns probable values of deviations for the various backlash sources.

Probable backlash can be analyzed in steps according to the major divisions of backlash sources listed in *Table* 7.

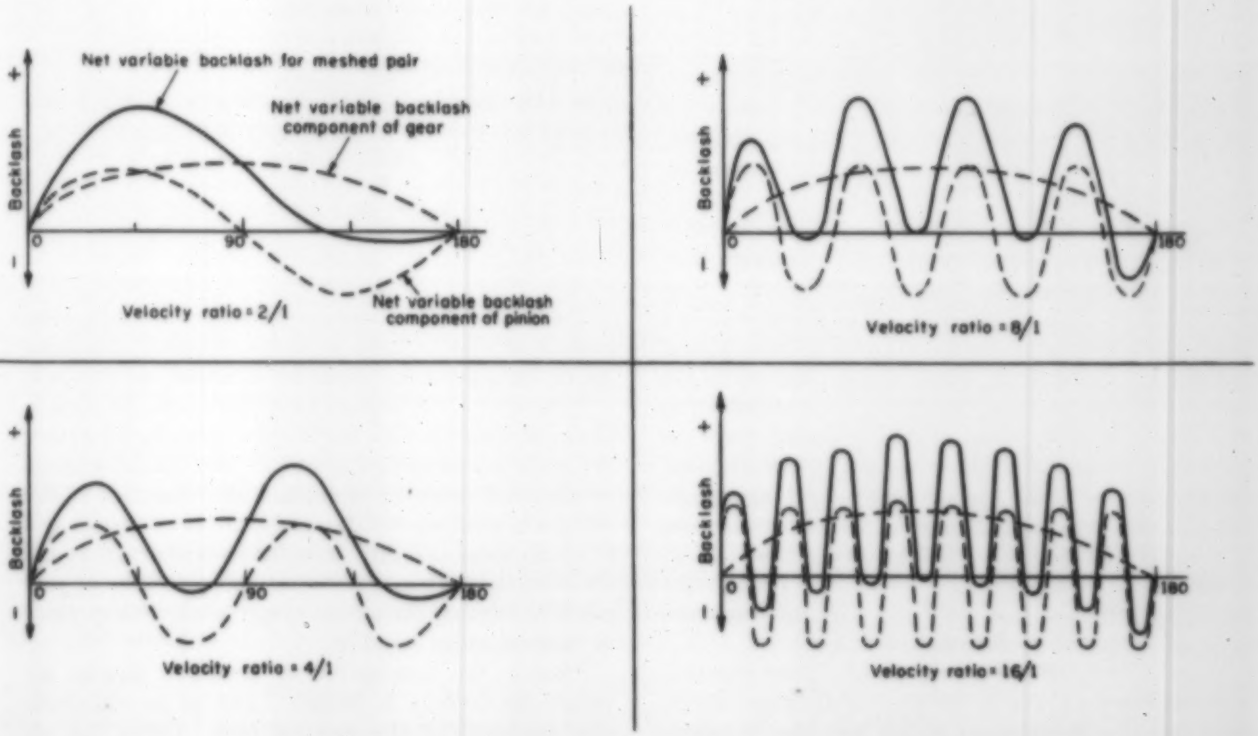
Design backlash (Group A) for each gear mesh of the train is fixed in value by design choice and no analysis is necessary since there is no probability about them.

Backlash components due to allowances and manufacturing tolerances (Group B) can be analyzed for probable values by applying proper probability factors from the study of manufacturing distribution curves or if these are lacking, by assuming factors based upon past experience.

Backlash components variable with rotation

Fig. 8—Examples of addition of net variable backlash components of mated gears for various velocity ratios. Equal variable backlash is assumed for each gear. Only positive half-cycles are shown; negative regions would be similar. Plus and minus notation on backlash axis signifies above or below average backlash value.

Plots show that net backlash for the meshed pair is the vector sum of each gear's backlash, or the net curve is obtained by modulating the gear backlash curve with that of the pinion. Probable maximum value of the net backlash for the pair approaches the arithmetic sum of the maximums of each component as the velocity ratio is increased



(Group C) are perhaps the most elusive; they are discussed in detail in the following section.

Phased backlash components include pitch circle runout, shaft runout and assembly runout which are essentially eccentricity errors. These factors have not only magnitude variation, but also have phase relationships, relative to each other, which will affect the net amount of backlash. Obviously, components which are in phase will add their errors together, and those components 180 degrees out of phase will tend to cancel one another. The various eccentric backlash components are independent of one another, and therefore have random phasing with no particular phasing more probable than another. The theoretical distribution curve would be flat as shown in *Fig*. 6. Such a flat distribution gives no clue as to a probable phasing value. A safe conservative approach, but not mathematically rigorous, is to assume only additive phasing angles spread as a flat distribution over 180 degrees as shown in *Fig*. 7. Then, the net sum of such vectors will be approximately 0.7 times the sum of their maximum values. This net sum can be assumed to be the probable backlash influence on a gear for all backlash components having phasing.

For a meshed pair of gears, each gear will have a probable net backlash figure which is derived as outlined. The phasing of these net backlashes in the mesh determines the effective operating backlash of the pair. For example, if the pair has a velocity ratio of 1, they could be phased in mesh so as to allow their low points of the pitch circles to mesh resulting in a backlash for the pair equal to the sum of the net backlash for each gear. On the other hand, their low and high points of mesh might be in phase, cancelling one another. Then, too, the phasing could be any angle between these extremes, the possibilities being limited only to the number of teeth in the gear. Again, the distribution would be a flat curve similar to the distribution of *Fig*. 6.

For velocity ratios greater than 1, the variable probable net backlash component of the large gear will be modulated by that of the pinion. The frequency of this modulation, of course, will depend upon the gear ratio. *Fig*. 8 shows typical examples. With such possibilities and with no indication of what is probable, a conservative phasing factor is wise. If the phasing error is limited to an assumed phase spread of 180 degrees, all additive phasing, the probable total net backlash for the meshed pair will be 0.7 times the sum of the components, for velocity ratios near unity. However, for larger velocity ratios, the probability factor approaches 1, if only the positive backlash cycle of the gear is considered.

Finally, backlash components which are variable with gear rotation will have an operating factor. Only for one position of mesh will the backlash component be at a maximum value. Either side of this position, its values will decrease until at 180 degrees away, this component becomes a maximum negative value, and actually decreases backlash from other sources.

Thus, the probable maximum value of the backlash component will depend upon probable position. Considering only mesh positions when the variable components are adding backlash to the system, for relatively high speed gears rotating many complete turns, the probable position or probable error will be one half the maximum, which is a reasonable factor to apply. However, sometimes a gear pair will only function for part of a turn such as the drive of a dial indication, in which case a more conservative probable operation factor should be used.

It is important to realize that backlash components variable with rotation go through positive and negative values. Of course, the integration over a cycle of positive and negative values of backlash is zero, but this is of little concern since the significant consideration is the momentary real value. Therefore, a safe and conservative method is to consider only one phase, the positive one.

An exception to the foregoing treatment of variable backlash components is the AGMA system of specifying total composite error. In this system, backlash due to tooth thinning and gear size tolerance is specified for the tightest point of mesh. Thus, any total composite error will add backlash to the system for all phase positions.

In summation, the net probable maximum backlash component of a meshed gear pair due to components variable with rotation, is obtained by means of the following steps:

1. Apply probability factors to each source of backlash such as total composite error, shaft eccentricity, ball bearing inner race eccentricity, gear bore-shaft clearance, etc.
2. Add the components and apply a probable phasing factor of 0.7.
3. After performing the foregoing steps for both gears of meshed pair, apply meshing phasing factor of 0.7 to the sum of the probable errors obtained for each gear for velocity ratios under 2, and a factor of 1 for higher ratios.
4. Apply an operational factor which will be dictated by the specific application.

The result will be the net probable backlash component of the meshed pair due to all the components variable with rotation, Group C of *Table* 7.

Note that in this discussion the backlash components referred to are the result of sources causing the pitch circle to be eccentric. The actual amount of backlash must be calculated as a function of the eccentric shifting of the pitch circle. Equation 1 is to be used for this calculation where ΔC is the eccentricity. This conversion can be made at any point in the calculation although a convenient place is between steps 3 and 4.

Finally, the summation of backlash figures obtained for Groups A, B and C will be the net probable backlash of the meshed pair. Often the entire procedure outlined for phased sources is omitted because these backlash sources are often very small compared with those of Groups A and B.

Multiple meshes have not been considered in the foregoing analysis. Actually, of course, the total probable backlash for an entire gear train is the sum of the probable backlash for each mesh measured at some designated point in the train. Obviously, gear ratio will modify backlashes of the meshes which are either above or below the speed of the place of measurement.

Inspection plays an important role since the suggested analysis of backlash prediction is based upon specified dimensions and tolerances applying to the influencing dimensions. These figures must be maintained if the calculations are to be of any significance. Any widespread disregard of tolerances, particularly the critical ones, will result in serious disruption of existing or assumed distribution curves with the result that the probable backlash figure will not be reliable. Therefore, inspection or equivalent insurance of all critical dimensions is necessary, and any departures from the design specifications must be accounted for in recalculation of the probable backlash.

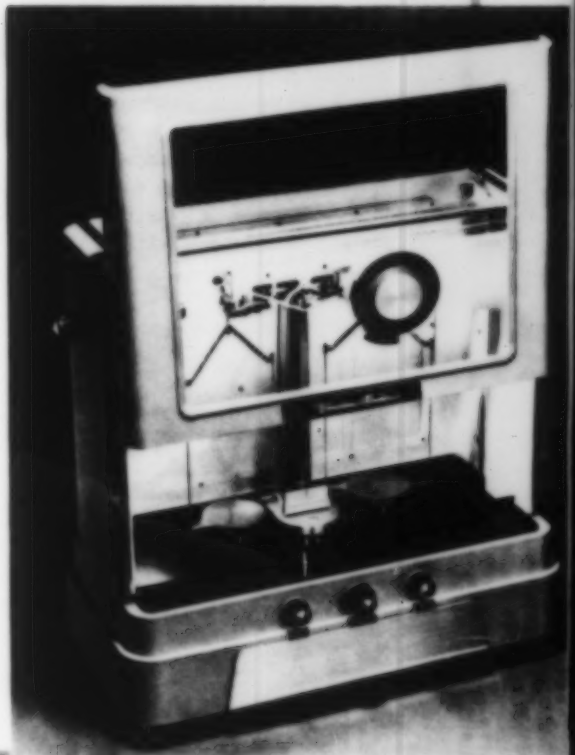
In summary, this discussion of backlash sources indicates the parameters which are to be considered in the design of precision gear trains. The listing is intended to be complete, but in any given application certain sources may not be present or may be negligible.

The next article in this series will describe methods for eliminating and controlling backlash. Also, a numerical example will be used for illustrating the procedures outlined in this article for calculating probable and maximum backlash values.

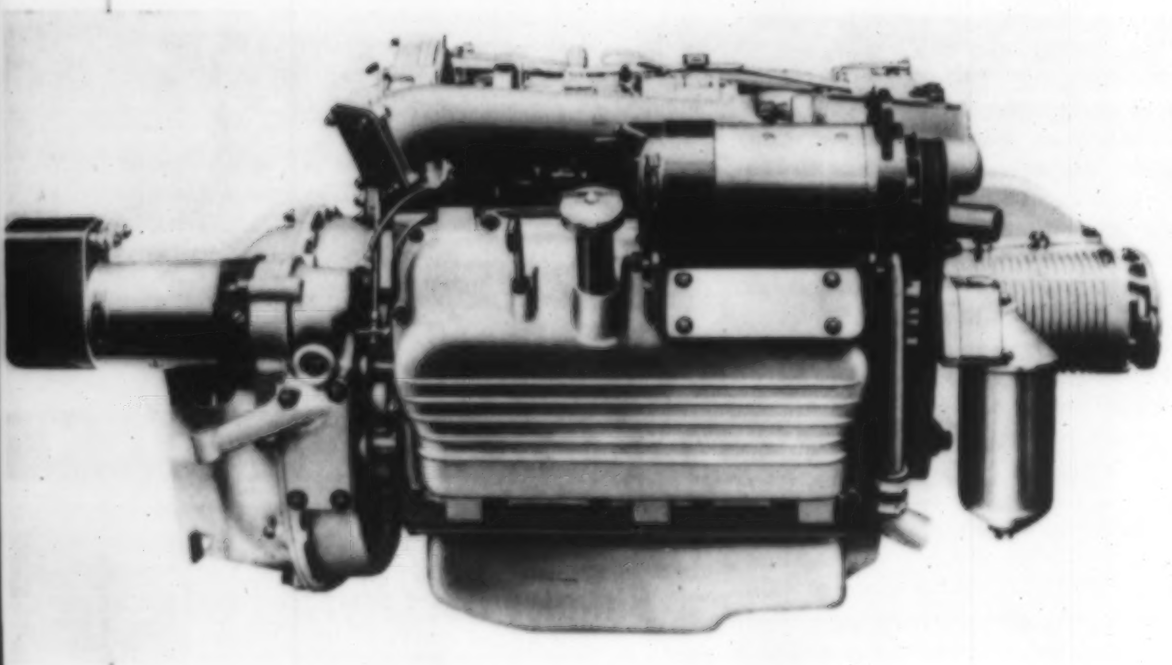
CONTEMPORARY DESIGN

Balance Uses Nylon Parts for Friction Resistance

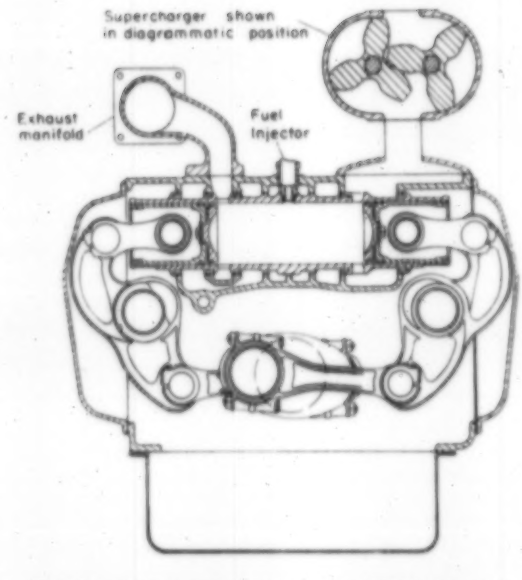
SMOOTH action without lubrication results from using nylon parts in a newly designed analytical balance for research laboratories. Nylon door and drawer channels are used on the Christian Becker balance manfactured by Torsion Balance Co. to provide quiet, smooth operation of the balance's vertical sliding front door and the small weight drawer. Two 13-inch long nylon bearing channels are snapped into the sides of the balance housing to serve as slides for vertical movement of the outside glass and aluminum door. These U-shaped channels are cut and formed from coils of Polypenco nylon strip 3/16-inch wide and 1/32-inch thick. These strips are hot-formed into a U-shape with a simple forming die and a hydraulic press. Nylon strip was also used for the drawer slide. Blanked and formed directly from the strip, the slide is cemented to a lip on the edge of the metal drawer. Another nylon part used is the pan arrest pin. This pin, serving as a cam follower, is machined from solid 1/8-inch diameter nylon rod on automatic screw machines. It has a rounded tip and is held in a horizontal aluminum bar by a simple set screw. In this position it rides against the brass cam at the end of the arrest shaft. Travel of the cam, as regulated by turning the dial, raises and lowers the delicate balance.

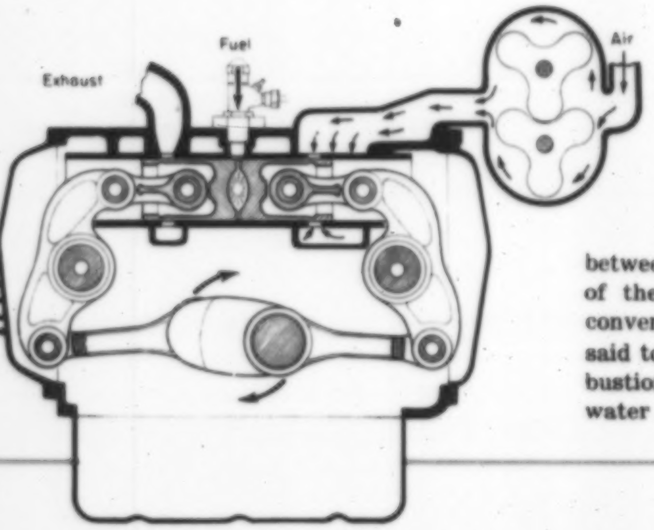


Novel Diesel Engine Uses Opposed Pistons

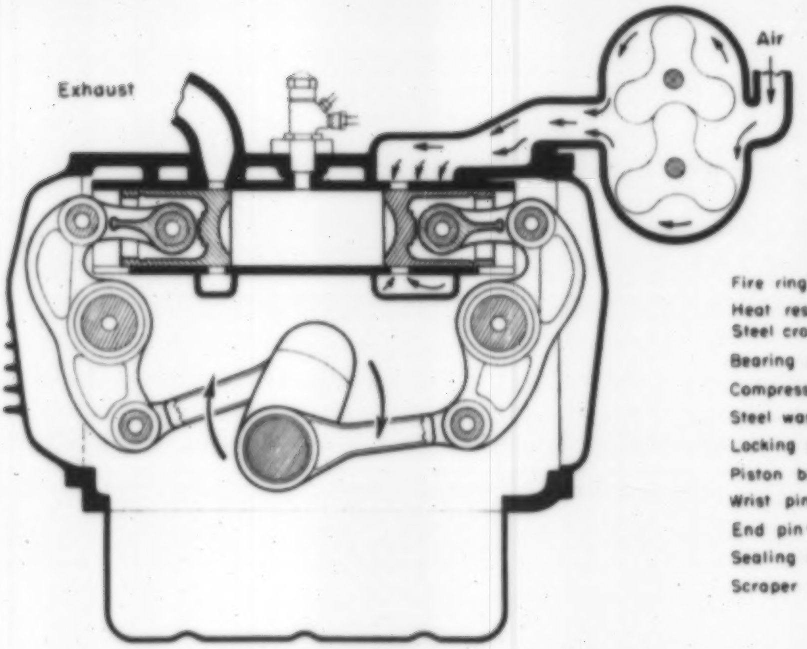


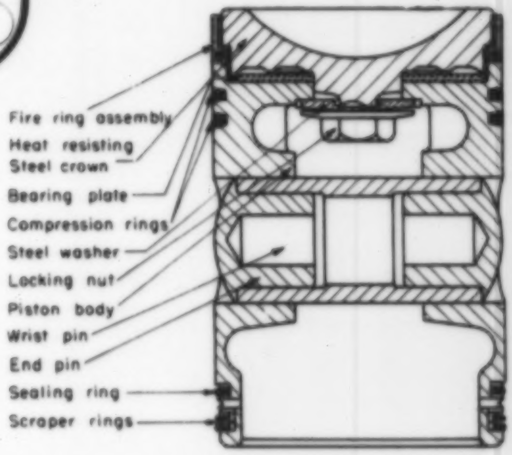
A NEW two-cycle diesel engine developed by Commer Cars Ltd., England, has its three pairs of opposed pistons linked to the crankshaft by piston rods, rocker arms and connecting rods. Each piston is connected to an individual crankshaft throw. Designed for underfloor mounting in passenger buses, the engine is 26¾ inches high, 36½ inches wide including air and oil filters and 44¼ inches long from the rear of the flywheel housing to the front of the fan. Dry weight is 997 pounds including auxiliary equipment. Bore and stroke are 3¼ and 4 inches respectively. Piston displacement is 199 cubic inches. Power output is 105 hp at 2400 rpm and maximum torque is 270 lb-ft at 1200 rpm.





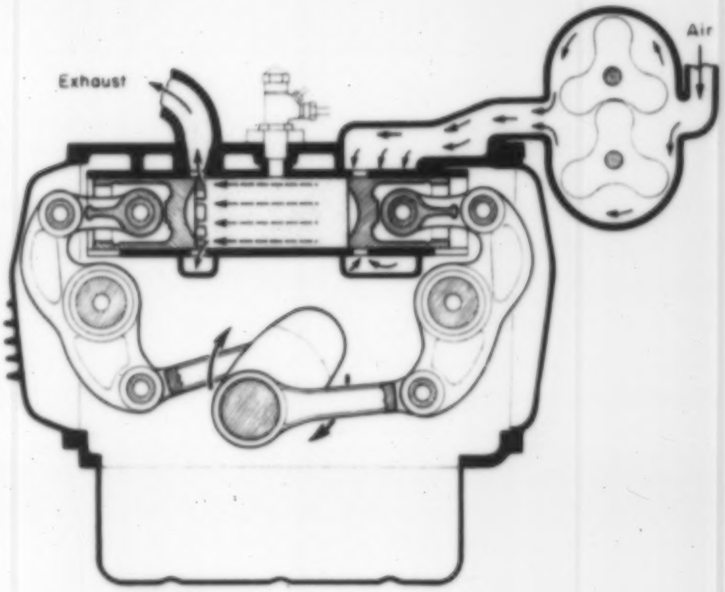
Combustion chamber of the TS-3 diesel engine is formed by two piston heads as they approach each other on the compression stroke. Fuel is injected into the space between the piston crowns and ignited by the heat of the air compressed between the pistons as in conventional diesels. High thermal efficiency is said to result from this construction since hot combustion gases do not lose heat to cylinder-head water jackets.

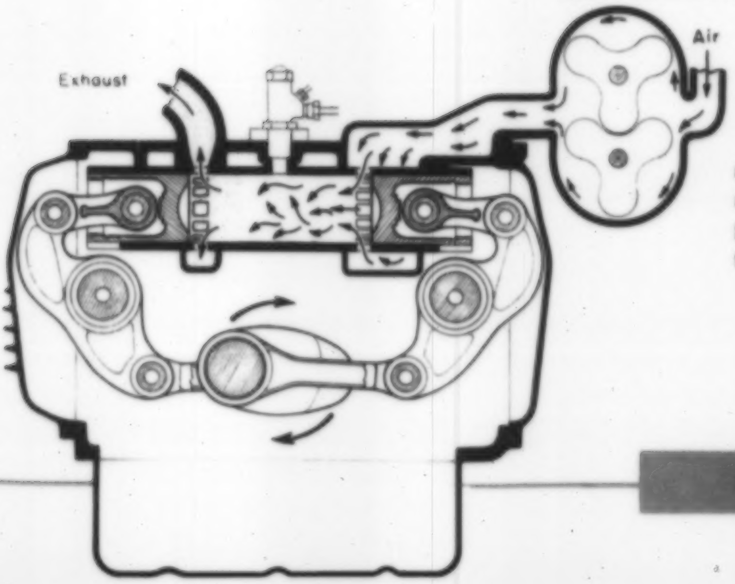

Exhaust
Air


Fire ring assembly
Heat resisting Steel crown
Bearing plate
Compression rings
Steel washer
Locking nut
Piston body
Wrist pin
End pin
Sealing ring
Scraper rings

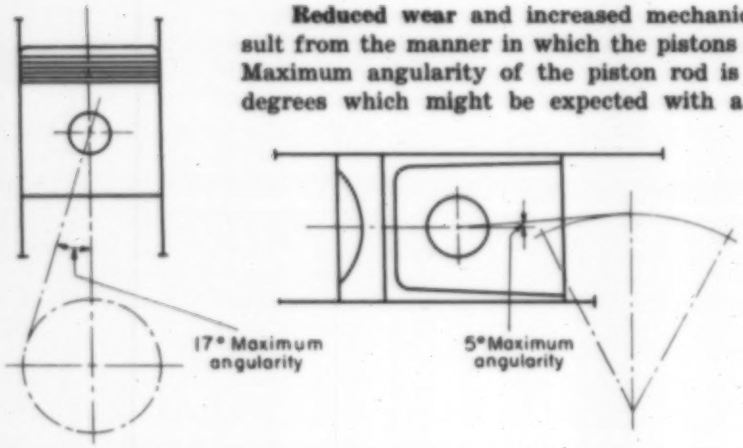
Expanding gases force the opposed pistons apart and rotate the crankshaft through their linkages. Specially designed pistons have steel heads which are thermally insulated from main body of the piston to prevent heat loss.

Near the end of the working stroke of the pistons, exhaust ports are uncovered by one piston shortly before inlet ports are uncovered by the other. Geometry of the ports and linkages controls the opening time.


Exhaust
Air

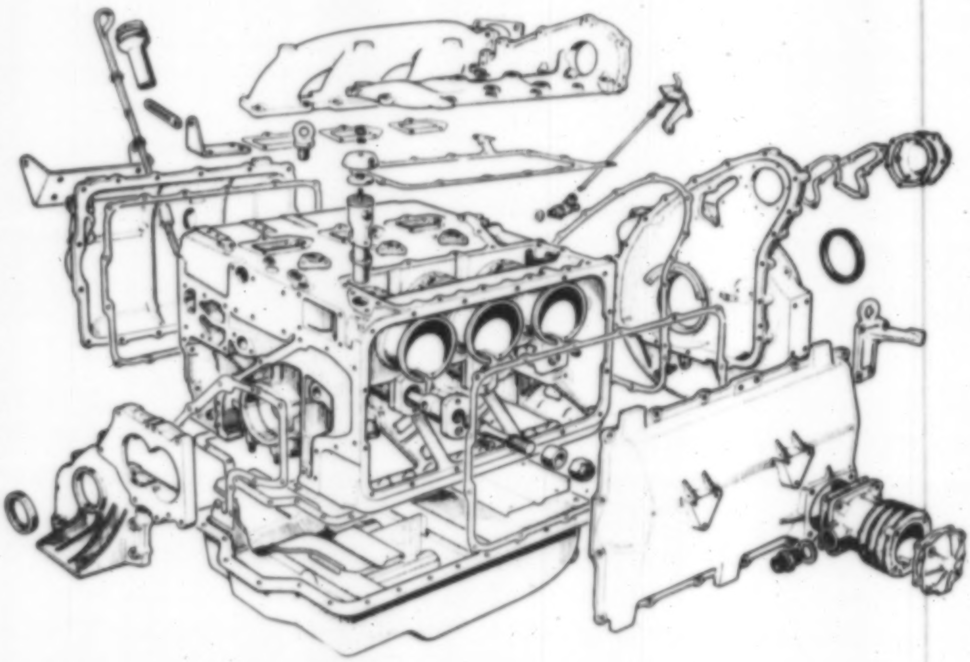

Exhaust
Air

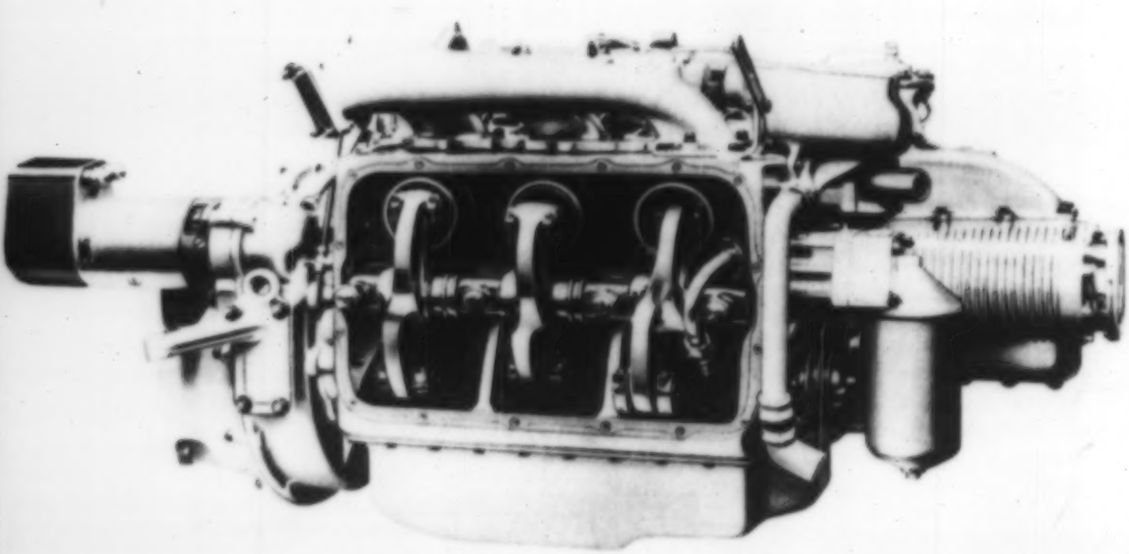
Inlet ports are uncovered shortly after exhaust ports allowing air from a Roots-type blower to enter and force remaining exhaust gases out through the exhaust ports.



Reduced wear and increased mechanical efficiency are said to result from the manner in which the pistons are linked to the crankshaft. Maximum angularity of the piston rod is 5 degrees as opposed to 17 degrees which might be expected with a conventional engine. Thus side thrust is reduced, reducing both friction and cylinder bore wear. Wear of crankshaft bearings is said to be reduced because the connecting rods transmitting power to the crankshaft apply equal forces at 180 degrees to each other.

Easier servicing results from engine construction. Large side covers allow access to and removal of rocker arms, connecting rods, pistons, piston rods, bearings and cylinder liners with the engine in place. When decarbonizing of cylinder ports is necessary, removal of the exhaust manifold assembly allows easy access.





Design factors in selecting and applying

FILTERS

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A FILTER'S sole purpose is to remove foreign substances from a fluid. But many factors are involved in selection of the right filter; ultimate choice is usually a compromise.

For example, a filter may be unusually effective in particle removal, but may not meet other desired conditions. In addition to particle removal, the filter must (1) be able to withstand reactions to harmful materials and to extremes of temperature, (2) have good retentiveness or cleanability, and (3) have a pressure drop within the usable range.

There are three basic methods of filtration: surface, adsorption, and depth. A few exceptions to these basic methods exist, and will be discussed.

Surface filtration involves removal of foreign particles by trapping them on the surface. Sometimes a cake of the particles may be built up on the surface and act somewhat as an additional filtering medium of the depth type, bypassing the filtrate through small passages similar to capillaries.

Fuid flow in a surface type filter may be expressed in accordance with a principle expounded by J. M. Poiseuille in 1843. This principle applies to a typical surface type medium such as wire screen constructed so that all particles are removed in one layer. As soon as each opening is blocked, its filtering function ceases, and it is no longer a factor in the filtering system. Pressure drop in a screen, therefore, builds up from zero to infinity—reached when each opening is blocked.

Paper media are of the surface type, but unevenness of the openings and the interlocking fiber structure present a slight depth feature as well. Many of the particles are caught in the fiber structure, while others pile up to form a cake such as previously described. This is the case for smaller particles but, at the same time, larger ones will block the whole capillary just as in a screen.

Although a wide range of materials has been tried for surface filtration, only a few have withstood the test of time. One of the oldest is the common screen, or wire cloth. This is the classical example of surface filtration. A large industry has been active in producing a variety of shapes, sizes, and materials for these

An Engineering History of Filters

Early uses of filters can be traced back 4000 years, when the Egyptians, Phoenicians and Greeks used material which was the forerunner of our modern paper to filter medicines, wines and beer. The straining of water and wine is depicted on tombs and other carvings around 1400 BC in Egypt. Plato and Aristotle have referred to the use of porous clay and wool fibers in their writings around 400 BC.

The word filter itself is presumably derived from the Latin *filtrum* or *feltrum,* meaning felt or compressed wool. Water filters were widely used by the Romans, and mentioned by such authors as Pliny in his *Encyclopedia.* Other references to the art are found in Sweden in the third century AD, and in Arabia in the eighth century AD.

The first filter patent issued abroad was to J. Amy in France in 1789 for a device with sponge or sand. In England, Peacock was granted a patent in 1791 for a series of filters. The earliest known patent on filtration in the United States was issued to Joseph Craddock of Baltimore on December 31, 1845. This was patent No. 4344, dealing with a filter for use in an ice chamber. Another early U. S. patent, No. 5404, was issued to John Watson of Jamaica on December 28, 1847, for a brush in combination with a sugar filter.

In the automotive industry, the history of filtration follows the growth of the automotive industry itself. The first automotive filter, designed and built by Motor Improvements Inc. in 1923, was a lubricating oil filter made in accordance with patents No. 1,594,334 and 1,594,335 by Ernest Sweetland. These filters contained a series of disks, embodying the then new extended-area principle in which the available filtration area exceeded the outer area of the filter housing.

Original form of this filter was known as a T-type and was designed for trucks. It consisted of revolving circular metal plates, covered by fabric, and stationary cleaning fingers. The housing could be separated and the plates removed. This was followed in 1924 by a lighter version, known as the A-type, for passenger cars. The housing was rectangular and included a sight glass for checking the condition of the oil, but the basic plate structure was the same as in the T. This form became highly popular on the automobiles of that period.

These basic designs were improved by adding automatic cleaners, changing the shapes of the disks, and other features. Up to 1929, Motor Improvements Corp. (a forerunner of Purolator Products Inc.) was the major company in the field, but in that year other companies became active. New designs were introduced; one such was known as the B-type, and was manufactured in large quantities—in fact, replacements for early installations are still being made today. Filtration was accomplished by a fabric bag wound on a helical spring to afford a large area.

In the middle 30's, the depth type filter element became popular. This design consisted of a mass of small fibers and particles, made of materials such as cotton waste or fullers earth, in a can or bag element. In this type of design the large filtering area of surface type filters was abandoned in favor of deeper cleaning action. A little later, full-flow filtration was introduced, and about this time the metal edge type principle, which is still widely used, became a practicality.

In 1937, the principle of impregnating paper and arranging it in extended area form was introduced. The first of these devices was arranged in disk form. Later developments included the pleated cylindrical type.

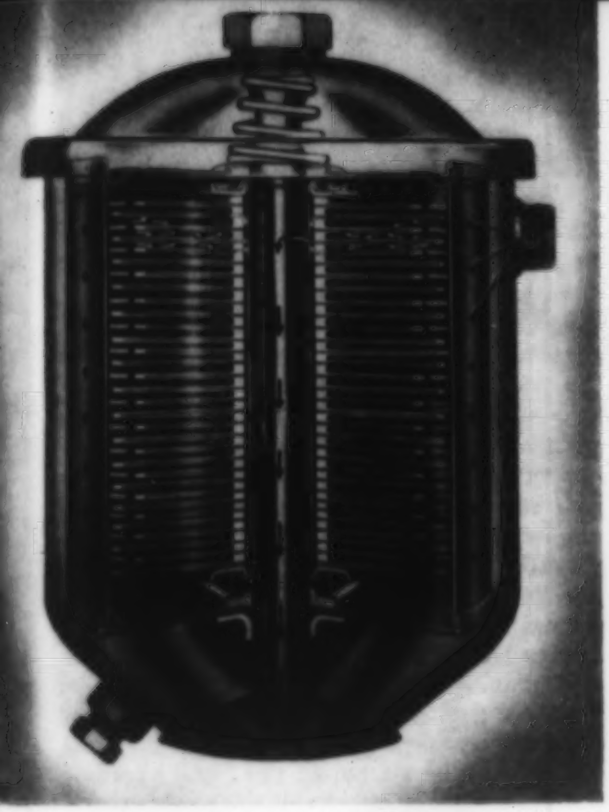
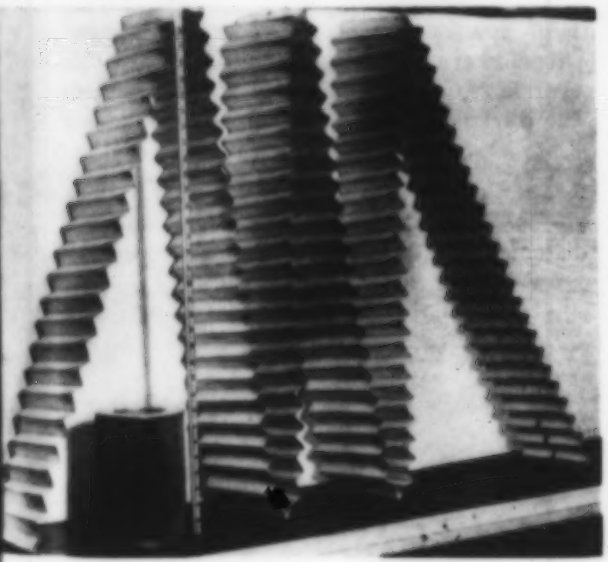


Fig. 1—Above—Disk type paper filter element

Fig. 2—Below—Pleated paper filter element with accordion-fold pack extended to show filtering area



single-layer filters. Corrosion-resistant materials such as stainless steel and Monel are especially used in sizes ranging from 2 mesh (2 wires per linear inch) down to 400 mesh (400 wires). Lubricating oil, water, air, gasoline and foods are often filtered through screens in mobile as well as stationary applications.

The terms "screen" and "wire cloth" have been used synonymously in the industry. However, these terms actually apply only to materials used for wet or dry sifting, which reveal a space between parallel wires. By contrast, in filter cloths used for filtration, no opening can be seen in the plan view.

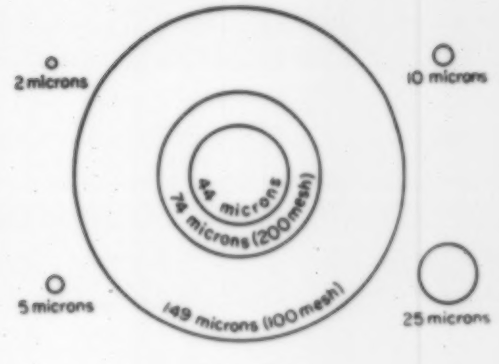
Differences in structure are due to the method of weaving, which results in a close twill. Wire cloths and filter cloths are especially useful where great strength and rigidity are desired or where cleaning is a problem. In many instances, these materials are used as backing for other media such as cloth or paper.

A widely used medium in this country today, especially for oil and gasoline, is paper which has been impregnated by resin. Early elements were composed of a series of leaves of paper impregnated with a polymerized resin such as phenol formaldehyde. The result was a strong, resistant filter medium with open pores to permit flow of the liquid being filtered. This principle was retained with changing shapes of elements—disks, spirally wrapped sheets, bellows construction, and accordion-pleated elements, *Figs*. 1 and 2.

The pleated type of element, for example, removes particles down to 1 micron in size, *Fig*. 3, and offers a large area of filter surface; an element which is about 4 inches in length and 3 inches in diameter offers a total of 570 square inches of surface.

One type of surface filter widely used is the edge type, *Fig*. 4. This type may assume many forms and be made of many materials. Metal may be formed with ribs and wound in either a helical

Fig. 3 — Relative particle sizes, screen sizes and linear equivalents



Linear Equivalents

Microns	Millimeters	Inches
25,400	25.4	1
1000	1	0.0394
1	0.001	3.94×10^{-5}

Screen Sizes

U. S. Sieve No.	Meshes per Linear Inch	Opening (0.001-in.)	Opening (microns)
50	52.36	11.7	297
70	72.45	8.3	210
100	101.01	5.9	149
140	142.86	4.1	105
200	200	2.9	74
270	270.26	2.1	53
325	323	1.7	44
400	.....	1.5	37

cylinder or in the form of a flat disk. A series of fiber disks may be formed and alternated with spacers to form an element. Whichever is used, the liquid filters through channels formed by the members, and impurities are removed by a shearing action at the surface of the "stack." The liquid passes on, but impurities larger than the openings are caught and held.

Quite frequently a cleaning scraper is attached to the unit to remove the accumulated impurities. Use of metal for this purpose may be especially appreciated where such high temperatures are involved that paper or waste would not be satisfactory. Experiments on certain acid-resistant materials, such as Teflon in disk or ribbon form, have been made on edge type devices, and some progress has been made in this direction.

Another development which has gained favor in the last few years has been the use of sintered materials such as iron, brass, bronze, stainless steel, glass beads, and the oxides of aluminum, iron or magnesium. A typical method for fabrication of these filters involves combining the powdered materials with a suitable binder and heating to just below their point of fusion to form a homogeneous mass which contains cellular channels throughout. Common uses of these sinterings include automotive gasoline filters for straining the fuel from the tank to the carburetor, and engine oil filters. These materials are finding increased use in the chemical industries.

Adsorption filtration occurs, basically, when contaminants adhere to the surface of the filtration material. Contaminants not only adhere, but also penetrate; the principle is widely used where straight mineral oils are to be filtered. However, detergents and other useful substances are removed by adsorption, somewhat limiting such media for other oils. Adsorbent filter media include fullers earth, activated alumina, bauxite, kieselguhr, and charcoal. They are excellent cleaners and refiners of oil due to their large effective area and volume, but they are not practical for filtration of automotive lubricating oils containing additives because of these very characteristics; useful additives in oil are removed by the same adsorption process that removes harmful acids, asphaltenes, and resins. In addition, a high pressure drop occurs where a high rate of flow of oil is maintained, and care must be taken to prevent the media from passing into the stream of the filtrate because of the abrasive effect of the earth.

Depth filtration is typified by such media as cotton waste or diatomaceous earth which act by adsorption, *Fig.* 5. Since a long, tortuous path of flow is presented, chances of removal of particles are considerably enhanced. In this type of filtration, the particles actually adhere to the surfaces of the medium, or are pulled

Fig. 4—Edge type filter element, which removes impurities by shearing action at the edge of the element

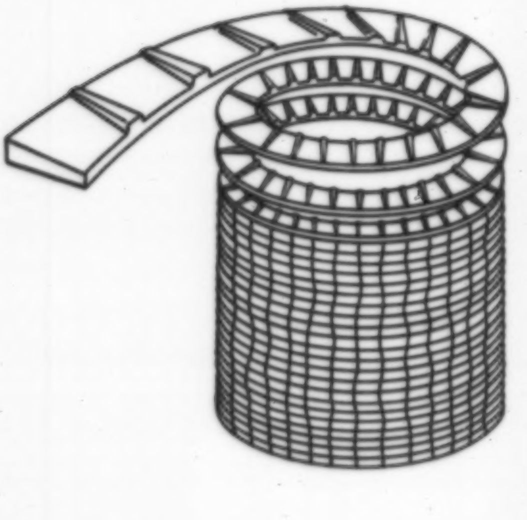
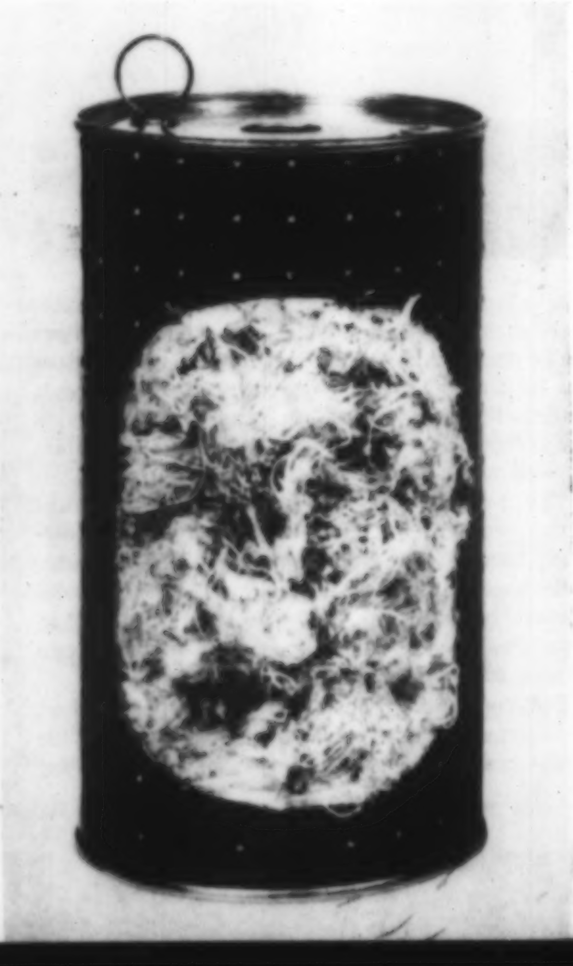


Fig. 5—Depth filter, using cotton waste, diatomaceous earth or similar media



Glossary of Filtration Terms

Abrasive: Any solid material, such as grit, with erosive properties.

Absorb: To take up by cohesive, chemical or molecular action.

Adsorb: To take up by adhesion of molecules of gases or dissolved substances to the surface of solid bodies, resulting in high concentration of the gas or solution at place of contact. Gas or solution is condensed on the surface of the adsorbent while in absorption the material absorbed penetrates throughout the mass of the absorbent.

Agglomerate: To gather or accumulate.

Ash test: A test to determine the weight of solids separated by a filter. The known weight, after burning, of a new filter is subtracted from the weight, after burning, of the filter to be tested.

Asphaltene: Product of partial oxidation of oil.

Asphaltum: A compact variety of bitumen, referred to as base of some oils.

Backwash: Reversing of flow to clean off a filter surface.

Back pressure: In filter use, resistance offered by filter, usually measured in psi.

Bleeder: A system in which part of the fluid from the main flow is diverted.

Blotter test: A visible means of checking oil clarity; one drop on a blotter will concentrate dirt or foreign matter in the center of the ring.

Bypass: To divide an oil stream, taking a metered amount through a filter.

Cake: Formation of impurities built up on an element.

Canton flannel: A twill weave, specially napped cloth used in filters.

Cartridge: A replaceable filtering device.

Channel: A passage through a filter medium without filtration.

Clarify: Filtration to transparency of a specified liquid, usually a visible inspection against light of the liquid in a test tube.

Cloud point: Temperature of a petroleum oil at which paraffin, wax or other solid substances begin to crystallize out or separate from solution when the oil is chilled under definite prescribed conditions.

Coagulate: To clot or curdle.

Colloidal carbon: Gelatinous nonsoluble black film in used oil, usually separated by absorption rather than mechanical separation.

Conradson test: Means of determining the amount of carbon residue left on evaporating an oil under specified conditions.

Continuous operation: In filter use, a filter capable of being cleaned without stopping the circulating system.

Deposit: In filter use, residue left on surface in filter medium.

Depth: In filter use, thickness of filter mass to be penetrated.

Diatomaceous: Refers to shell deposits of a plant or order of minute algae refined for filter use.

Discoloration: Change of caste or bloom of a liquid, usually in oils.

Dust: Suspended solid impurities in air, usually powdered earth.

Edge filter: Filter using shearing edges to separate solids from a liquid by shearing the oil film surrounding the solid particles.

Effective area: Area of a filter capable of filtration.

Element: Filter unit to be replaced as an insert of a filter housing.

Extended area: Surface area greater than the container.

Externally connected: Filter having pipes to transport oil to and from it.

Filter life: Span of operation from start to complete plugging, measured usually in hours of operation.

Filter medium: Material which performs the actual process of filtration.

Filtrate: Liquid which has been filtered.

Flow rate: Time required for a fixed volume of liquid to pass through filter.

Flush: Process of hydraulically cleaning the residue from a filter by washing.

Free acid test: Test showing the amount of uncombined acid contained in the oil. This, for mineral oils, is sulphuric acid coming from the refining process; with the organic oils it is an indication of age or rancidity and is often oleic acid.

Fuel soot: Black substance formed by combustion, or disintegrated from fuel in combustion using fine particles; fine powder, chiefly carbon, which colors smoke and is the result of imperfect combustion.

Full flow: Filter installation taking all the oil passing in a system.

Fullers earth: Soft clay used for fulling cloth and removing greases; used in some types of filtration.

Grit: Material separated from oil which has abrasive qualities.

Gumming test: Test performed by treating the oil to be tested with acid, which brings about in a short time the changes that take place in an oil when used. It is also a measure of the extent to which an oil will carbonize in a gas-engine cylinder.

Internally connected: Filter installed without external pipe. Openings to and from one part of a filter unit.

Iodine number (or value): Represents the percentage of iodine absorbed by an organic oil under fixed conditions; used in detecting adulteration.

Kieselguhr: Diatomaceous earth, found as a deposit, used for some types of filtration.

Maumené value: Rise in temperature (deg C) produced in mixing 10 cc of strong sulphuric acid with 50 grams of oil in a jacketed beaker; used to detect adulteratives.

Mesh: Openings or interstices of a screen.

Parallel: Passage of liquid through two or more filters independently so that the stream is divided to each, increasing area of filtration.

Penetrability: Susceptibility of being entered, as in comparison of one medium to another.

Plugged: Condition whereby a filter has become inoperative by collecting its capacity of contamination.

Poiseuille's law: Expression of relationship involved in flow of liquid through a capillary.

Pressure filter: Filter requiring pressure exerted through a closed system.

Purify: To filter until liquid is as pure as its original state.

Resistance: In filter use, the power offered against pressure to pass a liquid through a medium.

Saybolt universal seconds (SUS or SSU): Time in seconds required for a certain quantity of oil to flow through a standard orifice at a standard temperature and pressure.

Scraper: Knife used to clean the surface of a metal filter.

Separator: Any of various apparatus for separating liquids of different specific gravities.

Shunt: Filter installation in which increasingly more oil bypasses the element as the latter becomes contaminated.

Slot area: Area of the openings in the medium through which a filtered liquid passes.

Sludge: Mud, mire; combination of water, dirt, carbon and ingredients found in oils.

Soap test: Test to determine whether the viscosity of oils has been artificially and temporarily increased in order to pass specifications. An occasional recourse is the addition of a small percentage of "dope," "oil thickener" or white gelatin. This greatly increases the viscosity and causes the oil to chill more easily and to emulsify, thus increasing friction.

Solid suspension: Solids in a liquid which will not settle out.

Surface filtration: Use of an exposed surface as the filter medium; cloth, metal, paper, etc.

Suspension: Solids or liquids held in other liquids.

Turn-over: Number of times crankcase oil passes through a filter per unit of time.

Waste: Fibrous material used in depth-absorption type filters.

into the interior of the units comprising the medium.

Poiseuille's law may be applied to depth type filtration as well as to the surface type. The principal difference is that the cake forms within the filter medium, so that a different type of resistance to flow occurs.[*]

Most of the currently used depth filters, especially those used for oil, employ waste or other fibrous material, usually in throwaway cartridges. Examples are cotton fibers, cotton or wool waste, chopped cellulose, wood pulp, felt, flannel, hair, asbestos, crumpled paper, glass fibers, and various vegetable fibers such as hemp and ramie. All these materials remove the coarser particles as well as fine oxidants, some water, and certain acids. The materials are packed into a can or sock and the flow may be radial or longitudinal, depending on the design.

Density of packing is the factor which controls flow. Filtration may not be consistent—a small particle may be trapped in one channel, while a larger one may pass through in another. This last effect is usually overcome by careful packing, however, and particles down to 10 microns in size can be removed.

Depth type filters have also found use in the form of wire meshes, both dry and oiled types, as applied to carburetor air intakes.

Special filters, in addition to the types listed previously, may be important in particular applications. Magnetic filtration is accomplished by the use of a number of permanent magnets strategically placed to pick up metallic particles. In automotive vehicles, the filter is sometimes a drain plug in the crankcase, or it may be constructed in baffle form to present a larger filtration area. Usually the magnets are used in combination with some other form of filtration.

Centrifugal filtration, or separation, has been known for many years in such forms as laboratory centrifuges and cream separators. This is merely the application of the well-known centrifugal principle to free liquids of suspended insolubles, and a common use is purification of oil. Capacity of the device depends on viscosity, temperature, degree of purification desired and amount of water present. Large size and weight, and high cost of these devices, prevent their use in most ordinary cases.

Electrostatic filtration, in the form of precipitation of particles in air, has been widely used for many years. Smoke in industrial plants has been quite effectively controlled by this means, and air in heating and cooling systems has been kept free of impurities. There are two basic methods of utilizing the electrostatic principle. The most common is by applying an electrical charge to a plate and attracting polarized dirt particles to this plate. The other is by taking advantage of the electrostatic charge present in certain materials, such as polyethylene segments, or Canadian wool resin fibers. In the latter, voltages of over 1000 volts per centimeter have been known to exist along the filaments. Smoke particles ranging in radius from 0.2 to 0.5-micron have been removed. It may also be possible to apply the electrical electrostatic charge to liquid filters, but this is a comparatively untouched field.

Application of sonic waves is another interesting field of exploration. Such waves cause coagulation of suspended particles, due to increased rate of collision, or movement of particles to collection points depending on the type of treatment. In a continuous-flow system, the liquid is passed upward in a chamber exposed to a sonic field. Rate of flow must be less than the settling rate of the agglomerated impurities which form and drop out of suspension. The necessarily slow rate of flow somewhat limits the uses of such systems. More versatile, perhaps, is the use of sonic agglomeration and standard filter media in combination, with the latter removing the agglomerates.

One of the limitations of the sonic system is that dispersion instead of coagulation, may take place under some conditions. Dispersion occurs under atmospheric conditions when the sound field has an energy density of 6.6×10^{-6} watt-seconds per cubic centimeter. Calculations have been made which establish the relationship between particle size, attraction, density, particle concentration, and rate of flow.[†]

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[*] Shelby Miller in *Chemical Engineering Progress*, Vol. 47, No. 10, October 1951, Page 497.

[†] *Handbook on Aerosols*, Atomic Energy Commission, 1950.

Selecting a Filter

Methods of filtration and filter media have been viewed broadly, but the problems involved in filtering specific fluids must also be considered. Those most frequently treated are air, lubricating oil, fuel, coolants, hydraulic fluids, water, and special materials such as food and paint.

Air: Filtration of air involves removing impurities by various methods and media. These may include electrostatic precipitation, sprays, wire mesh, fibers such as glass and hair, paper, or adsorbents. Each will be discussed under their specific applications: automotive, aircraft, industrial, and household.

In automotive engines, air continuously enters the carburetor, and the oil reservoir (through the breather), during operation. Air is laden

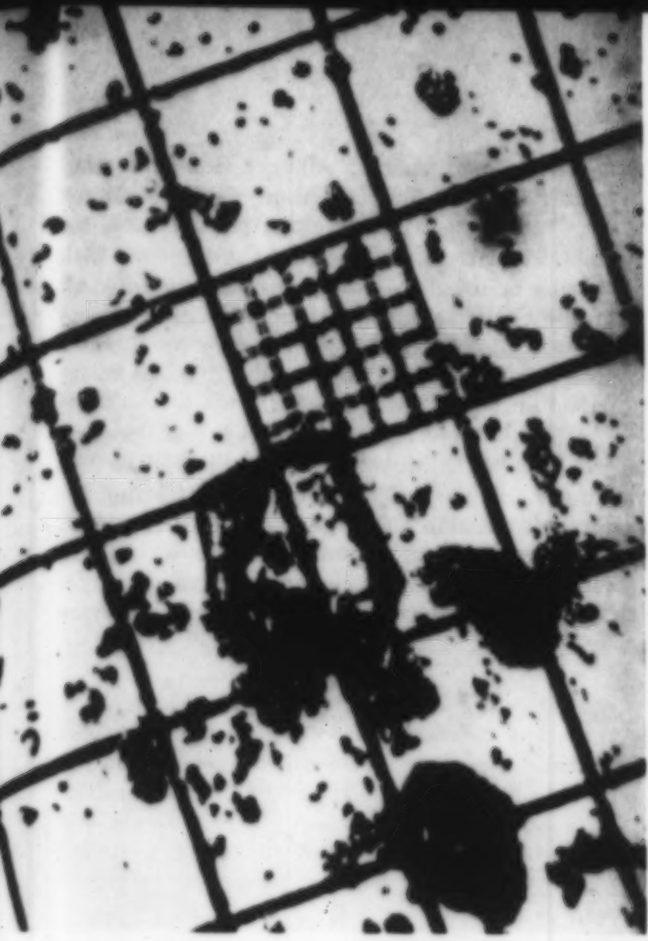


Fig. 6—Above—Microphotograph of dust sample. Small squares are 5 microns on a side

Fig. 7—Below—Dry type automotive air cleaner

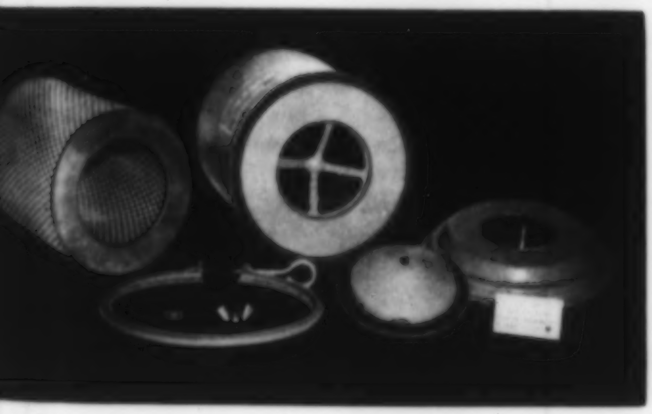
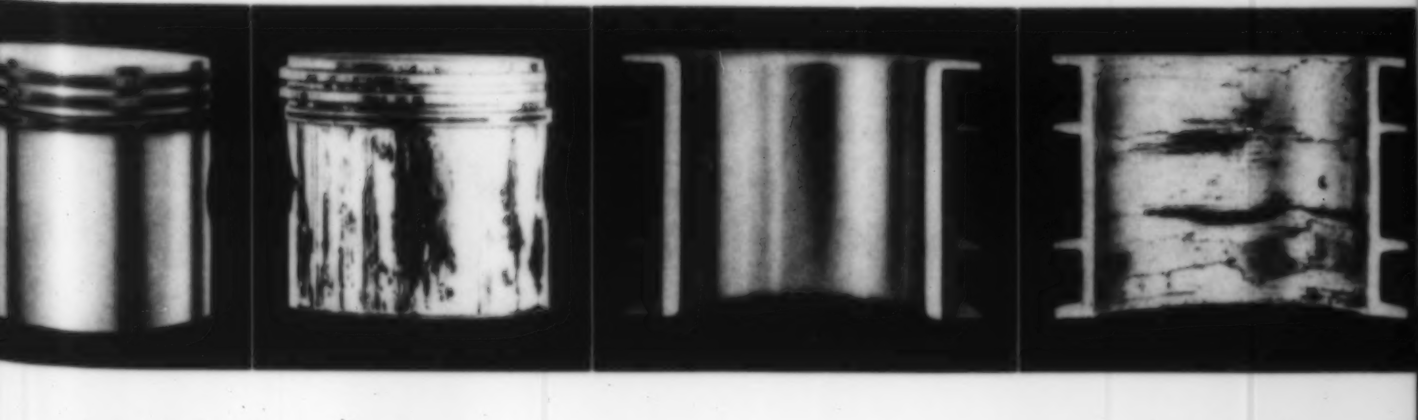


Fig. 8—Typical piston and bearing wear without filtration



with such impurities as airborne dust, acids, water, and unburned exhaust-gas products from other vehicles, *Fig.* 6. One usual type of automobile and truck cleaner consists of a mass of wire mesh or animal hair, or a combination of both, wetted by a spray of oil. As an adjunct to either of these, the filter may first impose a barrier which forces the air to change direction and drop some of its dust before it enters the main portion of the filter. This aids in preventing overload of the mesh portion of the filter.

In the oil-bath type, the air enters past an oil sump and entrains some of the oil. It is then carried over the mesh, the oil dripping back into the sump when the engine is at rest. Efficiency of this type of cleaner varies with the particle sizes present, ranging from 96 per cent with 5-micron particles to over 99 per cent with the largest particles.

One of the newer filters in automotive use is the impregnated convoluted paper type, *Fig.* 7, which eliminates problems of excessive or insufficient oil wetting as in the oil-bath type. Efficiencies are over 99 per cent with particles of all sizes. Dirt-holding capacity is high because the configuration exposes large areas to the flow and because collected particles are shaken free during operation. Pressure drops may be from 10 to 50 per cent less than with wet types. Installation and servicing may be simplified; however, unlike the oil-bath type which can be cleaned, the dry type requires an element replacement at regular intervals.

In aircraft, carburetor air intake filters are not widely used. This is due to several factors: the absence of impurities in the atmosphere, and a drop in engine manifold pressure which cannot be permitted. This drop may be as much as 2 inches of mercury in a 1600-horsepower engine. In special operations, such as those in desert country, a compromise is sometimes reached by using filters on the ground and during takeoffs, then cutting them out of the system in flight. These might be either a fibrous or a dry type. Use of air for operation of flight instruments creates additional problems, and a filter in the line may prevent malfunctioning of the instruments because of dirt.

Industrial air systems, such as pneumatically operated hand tools (hammers, riveters or screwdrivers), injection molders, air compressors, or forced-air cooling for turbines, are frequently improved by filtration. If the air being used is pulled in from the outer atmosphere, it may contain dust which is 20 to 40 per cent abrasive. A typical air sample may constitute soot, siliceous matter, coal dust, fibrous matter, bacteria, mold spores, pollen, acids and other matter ranging in size from about ½-micron up. Where electrical precipitators are used, the smallest particles may be removed but even with viscous or dry types of filters, substantially all of the particles down to 1 micron can be eliminated. Quite often a combination of a water spray and a medium such as cloth, glass fibers, paper or metal mesh is used.

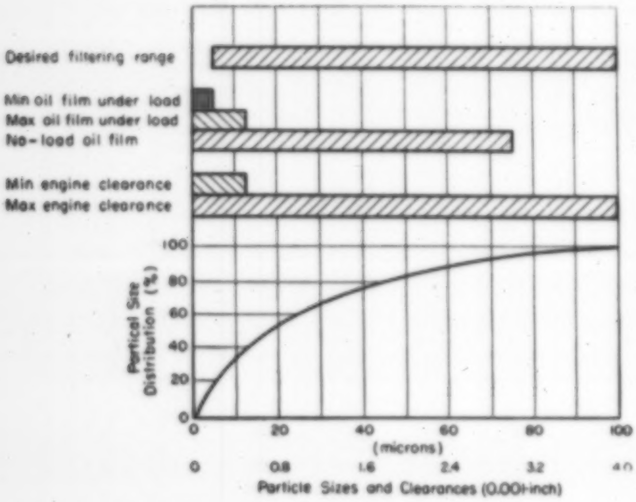
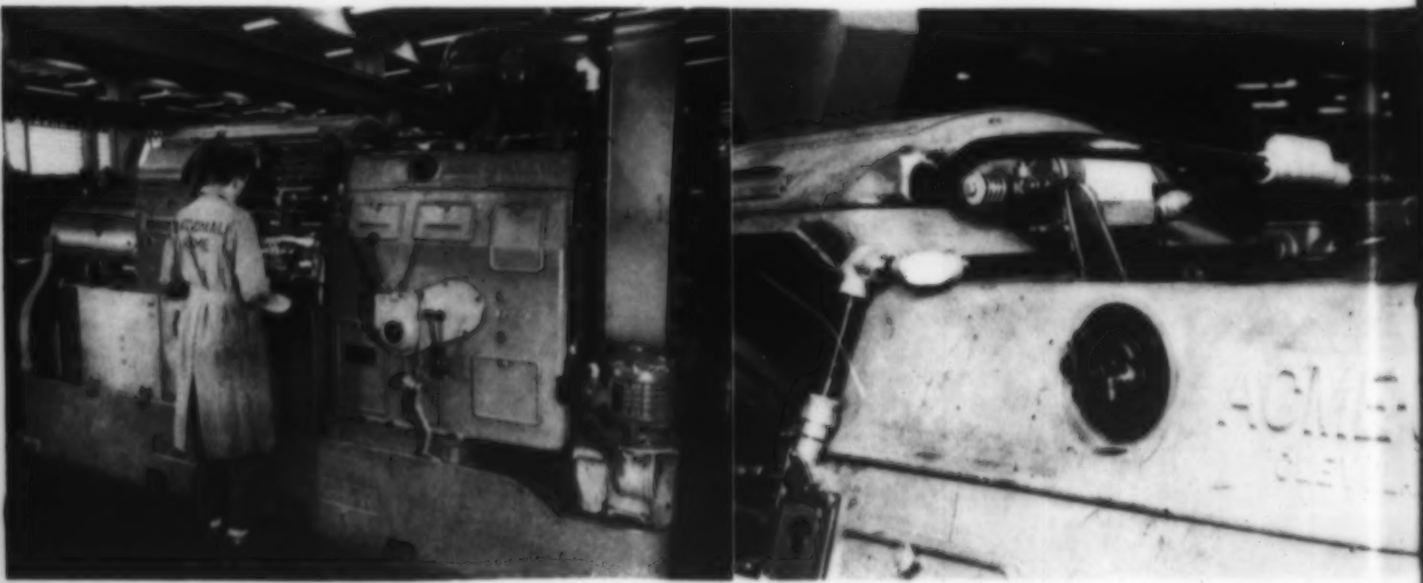


Fig. 9—Comparison of typical engine clearances with road dust sample particle distribution

Fig. 10—Built-in filter in the lubricating oil system of an Acme-Gridley bar automatic machine



All the impurities just listed also present problems in the average home, as well as the factory. Home heating and air conditioning require circulation of large quantities of air to be passed into our respiratory systems. Filters such as the viscous-impingement type, dry type, or electric precipitators are of immense service in preserving health and comfort.

Lubricating Oil: Lubricating problems have increased tremendously with the development of modern machinery, special lubricants and extreme operating conditions. The old nemesis, contaminant, is present in a hundred forms, and methods of removal must be found to avoid wear of the very moving parts the lubricant tries to protect.

Contaminants present in lubrication systems are: (1) the ever-present dirt in the atmosphere, (2) casting sand, (3) metal particles from wear or chipping, (4) water, (5) sludge, caused by fuel, carbon or coolants in the oil, (6) pieces of gaskets, seals or paint, (7) results of deterioration of the oil (caused by polymerization, or oxidation aided by the catalytic action of metals present) and low-temperature sludges, and (8) acids. These contaminants can cause a variety of damage to the machinery being lubricated; in automotive engines, for example, cylinders, main bearings, connecting rods and pistons usually suffer wear or scoring from such impurities, *Fig.* 8. Most of the damage is caused by impurities over 10 microns in size, because the oil film itself is 5 to 10 microns thick and carries particles in this range in suspension, *Fig.* 9.

In large industrial plants, such devices as settling tanks or centrifuges may be used, since space and weight are not important. However, smaller lubricating-oil filters, *Fig.* 10, are common. But in automobiles, trucks, railroads, airplanes and other vehicles, a small, highly efficient filter must be supplied, *Figs.* 11 and 12. These may be edge type, depth type, paper type,

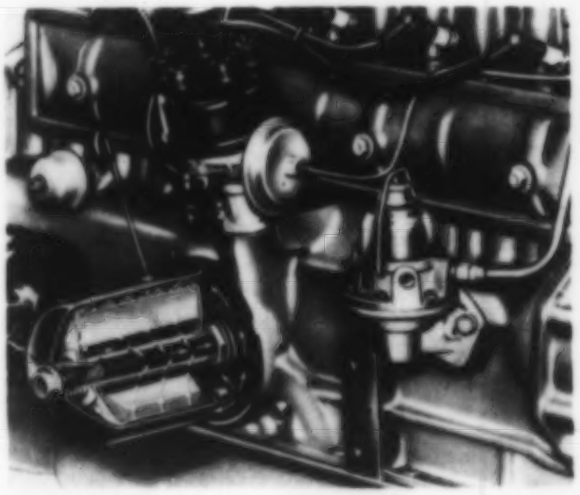
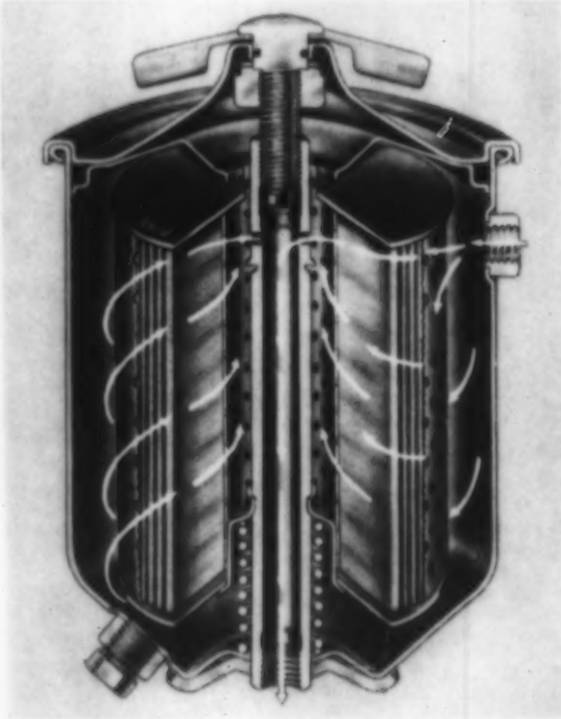


Fig. 11—Above—Engine pad-mounted filter

Fig. 12—Below—Externally mounted filter



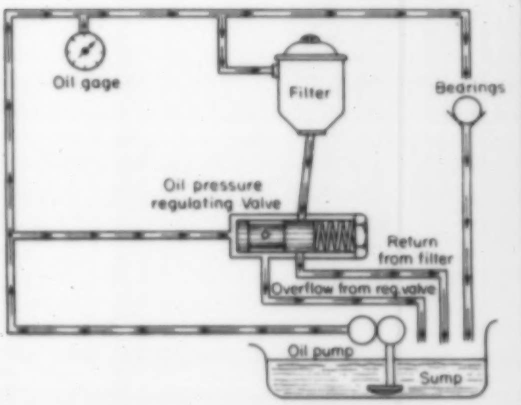

Oil gage
Filter
Bearings
Oil pressure regulating Valve
Return from filter
Overflow from reg. valve
Oil pump
Sump

Fig. 13 — Bypass filter installation, in which only part of the oil goes through the filter

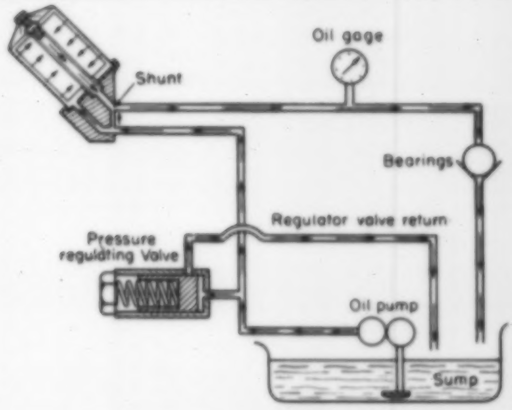

Oil gage
Shunt
Bearings
Regulator valve return
Pressure regulating Valve
Oil pump
Sump

Fig. 14—Shunt type filter installation, which starts out as a full-flow filter, but bypasses more and more oil as the filter element becomes loaded

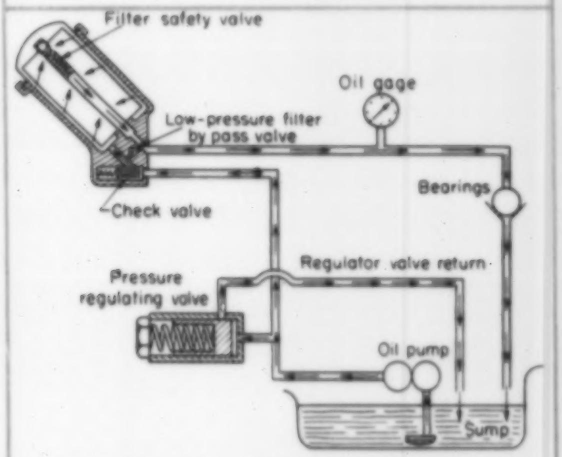

Filter safety valve
Oil gage
Low-pressure filter by pass valve
Bearings
Check valve
Regulator valve return
Pressure regulating valve
Oil pump
Sump

Fig. 15—Full-flow filter, in which all oil flows through the filter. Safety, check, and bypass valves are included to bypass oil under unusual conditions

or any of the others discussed previously.

In automotive engines, the three principal methods of filtration are the full-flow, the shunt and the bypass type, examples of which are shown in *Figs*. 13, 14 and 15. Similar systems can be used for other machinery. The difference among these systems is:

In the full-flow filter, *all* the oil passes through the filter so that contaminants in the system may be removed in one pass. This requires a large area of effective filtration. A relief valve is included in this filter in order to permit the oil to bypass the element in the event of unusual conditions. The bypass filter passes only a portion of the oil through the element—the remainder flows directly from the pump to the sump. The shunt filter starts out as a full-flow device, but contains a spring-loaded port through which more and more of the oil passes as the element becomes increasingly loaded with impurities. Comparisons of results attained with each method are shown in *Figs*. 16 and 17.

Additives in modern-day automotive lubricants have created additional problems. Additives perform many helpful functions such as corrosion prevention, oxidation stability and detergency. The first of these minimizes bearing corrosion due to the presence of acids; the second reduces high-temperature effects; the third holds in suspension carbon particles which would otherwise slip past piston rings and deposit on the cylinder walls. These particles primarily cause the dark color in the cleanest of oils. These useful additives must not be removed, which explains why the adsorbent type of filter has fallen into disfavor in this type of installation. Such filter media as impregnated paper, cotton or other cellulosic materials remove fewer additives; for example, cellulosic media removes about one-quarter as many additives as alumina, one-tenth as many as bauxite, and one-twentieth as many as fullers earth.

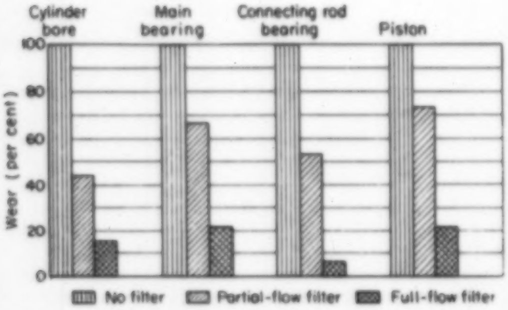


Fig. 16—Relative engine wear with two filtration methods. Wear with no filter is considered as 100 per cent

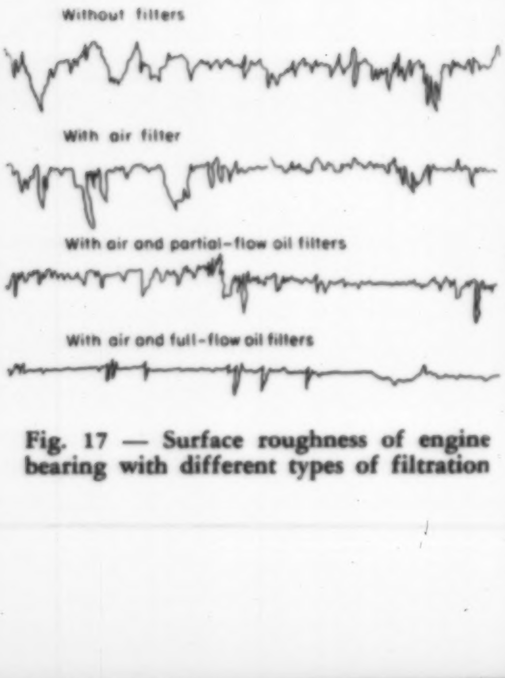
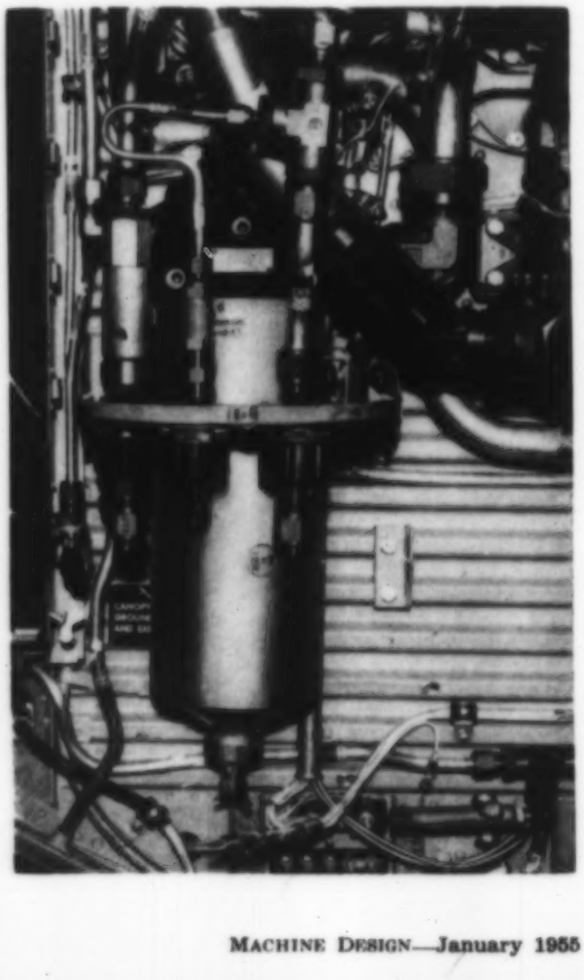


Fig. 17 — Surface roughness of engine bearing with different types of filtration

Fuel: Problems in the filtration of fuel are similar to those of oil, in many cases, since the contaminants present in gasoline, diesel oil and jet fuel are largely from the same sources. Extended-paper and waste type filters are in common use for all these fuels, *Fig*. 18, but screens and sintered-metal devices may be used where the amount of contaminants present is very small such as in ordinary passenger autos with sealed fuel tanks.

Diesel engines should be carefully protected

Fig. 18—Aircraft fuel system filter



from the deleterious effects of abrasive particles in the injection equipment, which can block the nozzle openings. Wear tests conducted by manufacturers and users of injection equipment have conclusively shown that wear is materially reduced by the use of proper filters.

It is becoming common practice to install filters in trucks conveying fuel to points of consumption, such as household oil burners, aircraft and gasoline stations, *Fig.* 19. Thus, most of the impurities are removed before they pass into the engine, and the smaller unit filter can more effectively remove any foreign matter that enters later.

Household oil burners largely use filters for the individual system, *Fig.* 20. Felt, waste, and impregnated paper are the most common types of media used for this purpose.

Coolants: Such machines as lathes, drill presses, planers, shapers, millers, grinders, screw machines, lapping and honing machines, sheet rollers and quenching machines all require coolant fluids. These fluids must be kept clean of impurities, especially where recirculation takes place.

Metal chips, of course, are the biggest problem; in addition, there are acids, asphaltenes, particles of polishing rouge, foundry sand, lapping compounds, chips off grinding wheels, gums, resins, airborne dirt, and bacterial growths. A few of these are harmless, but the large majority can scratch the surface of the product so badly that it may be unusable. Thread grinding, for instance, requires 0.5-micron elimination.

In addition to the effect on the work itself, it has been found that tool life may be seriously lowered—sometimes by 50 per cent—by the presence of excessive impurities. Bacterial growth on machines can take place in a surprisingly short time.

A further problem is created through the use of quench oils, which are exposed to local temperatures of over 1600 F during the process of quenching. Rapid heating of the oil by the metal will oxidize the oil and form asphaltenes which precipitate into the system and must be removed.

Several types of filters are used to remove these impurities. For larger plants, settling tanks and continuous belt type filters may be used in combination, or a central reclaiming operation may be substituted. Other types of filters in common use are magnetic for removal of metal chips—usually of the permanent-magnet type; centrifuges; fullers earth types; metal-edge types; absorbent types; and extended-area paper types. Any of these may be used in combination with any other.

Hydraulic Fluids: In industrial machines, automotive vehicles and aircraft, hydraulic fluids must be filtered to remove the same sort of impurities which are present in other types of

Fig. 19 — Filter installed on aviation fuel tank truck

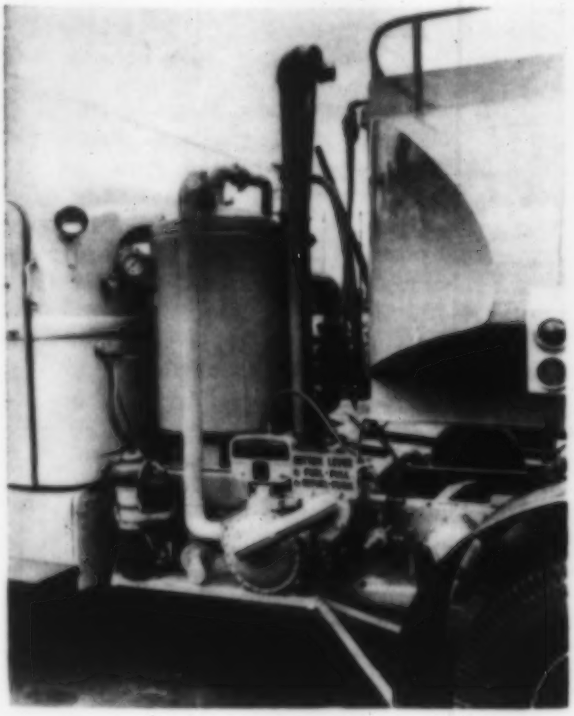
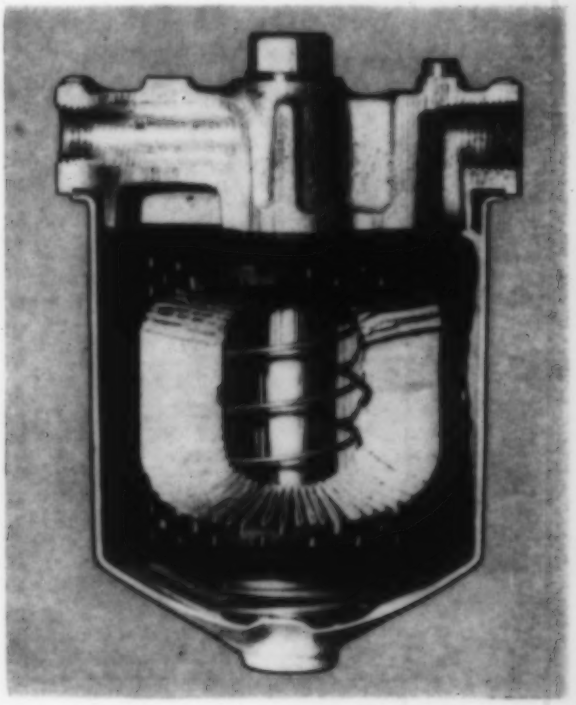


Fig. 20—Oil burner filter



fluids. Hydraulically operated machinery requires fluid that is kept clean of rust, dirt and other contaminants. Metal-edge and continuous-belt type filters have been widely used.

In aircraft hydraulic systems the fluid must be kept scrupulously clean because of the critical nature of the mechanisms. Wing flaps, automatic pilots, cowl flaps and other servo-operated devices can easily be jammed by a small quantity of impurities. Leakage of fluid around fittings, packings, and gaskets could easily be caused by these particles. Cleanable metal-edge type elements are effective for removal of practically all particles; paper elements are capable of finer filtration but are usually combined with metal elements to prevent metal slivers from puncturing the paper.

The filter is usually placed ahead of the pump in the hydraulic system, and is installed in either full-flow or bypass design. Gages are often included to indicate pressure drop across the filter so that the operator will know when the elements are to be changed.

Water: Although the larger field of filtration of potable water will not be discussed, filtration of water used in steam and hot-water boiler systems should be mentioned. As in all high-temperature vessels of this nature, a certain amount of scale, rust and dirt is present to clog lines, cause water hammer, and reduce efficiency of operation. Although gravity or pressure type sand filters are often used, and similar filters using less soluable materials, the extended-area paper element has also been satisfactory in this type of installation. It may be installed in the line and discarded when clogged, or backwashed to remove the sludge.

Special Problems: Filtration has proved to be an important factor in the manufacture and use of sugar, soup, cheese, greases, soaps, toothpaste, cosmetics, adhesives and many other products. It might be said that "anything that flows through a pipe can be filtered." Most of these highly viscous liquids can be cleaned by an edge type filter, which combines fine particle removal with low pressure drop and rigidity. Wire cloths or filter cloths are also used for many products. These filters must remove such matter as dirt, tinfoil, bobby pins, nails, lint, pieces of packing boxes, dead insects and so on well into the catalog of natural and artificial substances. In certain products, such as cheese, the filter performs the added function of breaking down large lumps.

CONTEMPORARY DESIGN

Sparkproof Lift Trucks Designed

VARIOUS measures have been taken in the design of a new series of lift trucks to eliminate the possibility of spark-ignited fires in hazardous locations. Developed by the Buda Co. Div. of Allis-Chalmers Mfg. Co., the trucks are diesel-engine powered and use no electrical equipment. A hydraulic motor is used to start the engine. Energy for the starting motor is provided by an accumulator which is normally kept charged by an engine-driven pump. A hand pump is also provided for charging the accumulator in an emergency.

Water cooling keeps the engine exhaust manifold temperature low and a special water muffler eliminates the possibility of sparks being discharged from the exhaust. Conductive tires prevent any accumulation of static electricity. Protective wood bumpers and forks of nonsparking metal prevent sparking if the truck should accidentally strike masonry or stone.

WHICH ELECTROPLATE?

A brief summary of the service properties, production possibilities and relative cost of plated metals

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MANY factors influence the choice of an electroplated coating. Appearance, corrosion resistance, wear resistance—to name only a few—may be the primary reasons. But often secondary benefits are obtained.

For instance, plated metals are often specified solely for their appearance value. A manufactured product with a good appearance has very strong customer appeal. Use of electroplated trim on automobiles is ever-present evidence of this fact. Much of this trim serves no useful purpose, and yet it is used year after year in a highly competitive, style-conscious market.

For many applications, corrosion resistance is the primary goal, independent of appearance. A metal deposit is often applied to protect the base metal from a corrosive environment in order to obtain satisfactory service life. Without use of a protective coating the base metal may be an uneconomic material.

Plated metals are often used purely for economic reasons. Corrosion resistance is an example, but a plated part is often used because it is the cheapest known process for manufacturing a part with the desired properties. A good example is electrotinned strip steel, which has replaced much of the older hot tinned type.

Thin metal coatings are also used for a variety of engineering applications. Such coatings are used to resist corrosion, decrease wear, decrease friction, maintain low electrical contact resistance, avoid galling, pick-up or fretting, obtain high reflectivity of light or high conductivity of electric current. Special applications are too numerous to mention, and new uses are being developed every day.

One or two of these factors may determine usage for a specific case, but the factors are often interrelated. Economic factors, as given in *Table* 1, apply primarily to the life of the deposit and

Table 1—Relative Ratings of Electrodeposited Metals

Metal	Corrosion Resistance*	Wear Resistance	Staining Resistance	Protection of Steel	Cost†
Cadmium	Poor	Poor	Poor	Excellent	4
Chromium	Excellent	Excellent	Excellent	Poor	3
Copper	Good	Fair	Poor	Good	7
Gold	Excellent	Fair	Excellent	Fair	1
Iron	Poor	Good	Poor	Good	7
Lead	Good	Poor	Poor	Fair	6
Nickel	Good	Good	Fair	Good	5
Rhodium	Excellent	Excellent	Excellent	Fair	1
Silver	Good	Fair	Fair	Fair	2
Tin	Good	Poor	Good	Fair	4
Zinc	Poor	Poor	Poor	Excellent	8

* Of deposit. † 1—highest cost; 8—lowest cost.

relative cost. Zinc and cadmium, for instance, have poor corrosion resistance but offer excellent protection for steel. On the other hand, chromium is outstanding in wear and inherent corrosion resistance but is poor for protection of steel.

Estimated hardness range and density for each metal are shown in *Table* 2. These properties are more or less academic, since hardness is very seldom measured. But they do indicate quantitative differences in resistance to abrasive wear.

Economic factors to be considered for the various plating baths are listed in *Table* 3. Each bath is definitely limited in characteristics. For instance, the alkaline tin bath has sufficient throwing power (ability to reach inaccessible surfaces) to plate inside of a cylinder where the length is much greater than the diameter. If a chromic acid bath were to be used for the same purpose, special and expensive racking would be required. The factors of *Table* 3 are only general and may become reversed for complex shapes or heavy deposits. It is quite possible to design a part for which there are no known plating methods.

Each metal has certain properties and applications for which it is particularly suited—and also certain limitations. The following discussion will outline these in more detail.

Cadmium: Cadmium is primarily used to protect steel from rusting. It is an alkaline metal and as such protects the steel by sacrificial corrosion. As long as the surface is covered the steel will not rust. Porosity in the deposit is not harmful, and life of the coating is merely dependent on thickness or corrosion rate of the cadmium.

Table 2—Hardness and Density

Metal	Density (gm/cc)	Hardness (brinell)
Cadmium	8.7	35–50
Chromium	7.1	700–1000
Copper	8.9	60–150
Gold	19.3	5
Iron	7.9	150–350
Lead	11.3	5
Nickel	8.9	150–500
Rhodium	12.4	400–800
Silver	10.5	50–150
Tin	7.3	5
Zinc	7.1	40–50

Cadmium is usually plated as a very bright deposit. Characteristics of the metal are very similar to zinc, except that it is supposedly more resistant to moisture and salt air. As a consequence it is commonly specified for naval applications.

Cadmium is not abundant and is expensive as compared to zinc. Therefore it should not be used where zinc will afford adequate protection.[1] Although available, it is a strategic metal, so time spent to evaluate the relative merits as compared to zinc might be justified.

Chromium: High hardness, excellent corrosion resistance, low coefficient of friction, and permanent brightness put chromium in a class by itself, both for decorative and engineering plating.

For decorative purposes an undercoat of nickel or of nickel and copper is used, since thin chromium deposits are porous. Undercoats are usually 0.0005 to 0.002-inch thick, while the chromium is only 0.00001 to 0.00002-inch thick.[2]

Heavy chromium deposits are used for an endless variety of engineering purposes, particularly where abrasive wear is an important factor.

Where the ultimate in wear resistance is not required, hard nickel should be given serious consideration as an alternate. Heavy nickel deposits have good corrosion and wear resistance and are cheaper to apply than chromium.

Copper: Because of ready staining, copper is not often used as a decorative coating. However, it has good corrosion resistance and can be deposited relatively free of pores to protect the base metal. It is therefore used as an undercoating for other deposits. Often it is preferred for such applications, because it is more easily buffed than the harder metals and so aids in producing a smooth surface to receive bright finished deposits.

Bright deposits can be produced with some cyanide baths, and heavy deposits can be applied from

Table 3—Economic Factors for Plating Baths

Metal	Bath	Plating Preparation	Plating Rate	Thick Deposits?	Throwing Power	Control
Cadmium	Cyanide	Easy	Fair	No	Good	Careful
Chromium	Acid	Easy	High	Yes	Poor	Easy
Copper	Acid	Careful	High	Yes	Poor	Easy
Copper	Cyanide	Easy	Good	No	Good	Careful
Iron	Acid	Careful	High	Yes	Poor	Careful
Lead	Acid	Careful	Good	Yes	Poor	Easy
Nickel	Acid	Careful	Good	Yes	Fair	Complex
Silver	Cyanide	Careful	Good	Yes	Good	Easy
Tin	Acid	Careful	Fair	No	Poor	Complex
Tin	Alkaline	Easy	Low	No	Excellent	Easy
Zinc	Acid	Careful	Good	Yes	Poor	Careful
Zinc	Cyanide	Easy	Fair	No	Good	Careful

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[1] References are tabulated at end of article.

the acid baths. These heavy coper deposits are used for electroforming of electrotype, sheet, screen and various shapes.

Copper is also used as a stop-off for selective carburizing or nitriding.

Gold: Gold is used principally for ornamental purposes. To keep cost down very thin deposits are covered with lacquer. Life of the deposit is thus dependent on life of the lacquer, since a few millionths of an inch of soft gold has a very short life.

Gold is also used for electrical contacts and infrared reflectors. It is a true noble metal and does not form oxide on the surface as do all the commonly used metals.

Table 4—Typical Electrodeposits

Application or Type of Service	Electroplate
Automobile trim	Chromium (nickel and copper undercoat)
Battery parts	Lead; lead-tin
Bearings	Silver and alloys; lead alloys; tin alloys
Break-in (pistons)	Tin
Build-up of work parts	Chromium; nickel; iron
Containers, chemicals and oil	Lead and lead-tin
Corrosion resistance, weather	Zinc; lead; cadmium
chemical	Specific for the chemical
oil	Lead and lead-tin; cadmium; copper-base alloys; nickel
voltaic-couple	Cadmium (over dissimilar metals)
Electrical contacts	Silver; silver-rhodium; gold
Electroforming, general	Copper (acid); nickel; iron
sheet	Copper; nickel
tubes	Nickel
screen	Nickel; copper
Floats	Copper (acid; electroformed)
Gun barrels	Chromium
Laboratory equipment	Silver; gold; nickel (copper undercoat)
Machines, food processing	Tin; nickel
Machines, laundry	Cadmium
Moisture resistance, general	Zinc
marine	Cadmium
structural	Lead
washing equipment	Cadmium
Molds (lining)	Chromium
Musical instruments	Silver; gold
Nuts and bolts	Lead; zinc; cadmium; nickel; chromium
Ornamental	Silver; gold; rhodium; nickel; chromium
Plumbing fixtures	Chromium (nickel and copper undercoat)
Powdered metal parts	Copper (acid); iron
Reflectors, general	Cobalt; silver (lacquered); chromium; speculum
infrared	Gold
Refrigeration coils	Tin
Rubber adhesion	Brass
Salvage of worn parts, general	Chromium; nickel; iron
Selective carburizing	Copper; bronze
Strike plating baths, general	Copper (cyanide)
silver-plating	Silver (cyanide)
cadmium adhesion	Cadmium (acid)
Tarnish resistance	Chromium; tin; gold; platinum; chromium (nickel and copper undercoat); nickel (copper undercoat)
Wear (hardness and low coefficient of friction)	Chromium
Wear (hardness and electrical conductivity)	Rhodium over silver
Wear (limited wear)	Nickel; iron
Wear (cylinder liners)	Chromium (porous)
Wire, steel	Zinc
copper	Tin

Adapted from Reference 5.

Iron: Good deposits can be obtained with good physical properties, and very heavy deposits are applied commercially, but iron is not widely used because of the ease with which it rusts.

For these reasons, use of iron is restricted mostly to electrotyping and electroforming. Deposits can be stripped from the mold and hardened by carburizing or nitriding. They can also be plated with other metals to obtain desirable surface properties.

Iron is relatively cheap to deposit as compared to nickel, and should be given consideration as an alternate for heavy nickel deposits. It is not a popular plating bath, due to limited usage, so that iron plating is usually not available in job plating shops.

Lead: Like iron, lead discolors rapidly. Also the metal is soft and has very poor wear resistance. Uses of lead are restricted mostly to applications where corrosion resistance to a specific environment is superior to other metals, such as battery parts. Lead-tin alloys are deposited for roofing and for sleeve bearing surfaces.

Nickel: Nickel is used in an extremely wide variety of applications and is deposited from many different baths depending on the base metal, thickness of the deposit, the application, and whether a bright, hard or soft deposit is required.[5]

Nickel deposits are relatively hard, have good corrosion and wear resistance, and can be deposited relatively free of pores over a properly prepared surface.

Although chromium may be a standard for decorative plating it would often be of little value without a nickel undercoat.

Nickel is used for engineering applications where demands for hardness and friction do not require chromium. It can be deposited as a softer metal, so that it is tough but not brittle and can be machined rather than ground. Also, it will not fracture in heavy sections.

Since nickel can be deposited as a tough, strong metal it is used for a great variety of electroforming applications for making of dies, molds and various shaped articles.

There has been a considerable amount of development work in recent years with tin alloys containing copper, nickel and zinc[4] that are potential substitutes for nickel in some decorative and engineering applications.

Rhodium: High cost limits the use of rhodium. However, very thin deposits have been found useful as a surface coating for silver in electronic applications. It is a hard noble metal with excellent corrosion resistance, good conductivity, and good wear resistance.

Silver: Silver is a standard for certain decorative applications, such as jewelry and flatware. Even though it is subject to tarnishing, the particular white color is demanded for certain luxury items.

High cost is a limiting factor for silver plating. However, metal cost can often be a minor item in terms of operating cost and results obtained.

Silver has become a standard for aircraft sleeve bearings and is used in considerable quantities for electrical contacts. Because of good corrosion resistance it is also used for chemical and food equipment.

Tin: Good corrosion resistance is the primary reason for use of tin. A high percentage of the tin produced is used for electrotinning of tin-can stock. It is also used as a rather pleasing protective coating for low-cost articles where a flash coating is desired. Many such applications are on copper, such as copper wire, or on copper alloys.

Because of its nontoxic qualities it is used in food processing equipment. Good corrosion resistance and antifriction qualities make it suitable for break-in and sleeve bearing surfaces.

Zinc: Zinc is standard for low-cost protection of steel. Protection is good due to sacrificial corrosion, and bright zinc plating is widely available. The metal is relatively soft and will corrode, so that life is dependent on thickness. It is used for a great many applications, both outdoors and indoors.

There is no good substitute for low-cost zinc, but there is evidence that a tin-zinc alloy[4] may combine the corrosion resistance of tin with the sacrificial corrosion protection of zinc.

Conclusion: Typical applications for these metal deposits are listed in *Table* 4. From these applications and the properties of the metals a selection may be made. However, for a typical application more than one metal is often used. Nickel may take the place of chromium; iron or alloys of tin may be substituted for nickel.

It is quite likely that alloy deposits will soon come into wider usage with a range of available properties. The applications of yesterday will not all be the applications of tomorrow.

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4. F. A. Lowenheim—*Modern Electroplating*, Electrochemical Society, New York, 1953, Page 434.
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Ideas industrial design

no tracing paper allowed

A short time ago, I had an experience which perhaps exemplifies the difference between a guy-who-just-draws-lines and designer. I should first explain that I think of a designer as a fellow who knows where the lines should go—and why.

My experience was simply this: a guy-who-just-draws-lines called me to his board, and said he was having trouble drawing a nice curve for a cast-iron lever. This could have stumped me (as he hoped it would). So, not knowing anything about the problem involved, I made a wild stab and suggested he make the lever straight. He turned it over in his mind, and then, with some embarrassment, admitted he thought it might be a good idea.

While mentally patting my own back in admiration, the question occurred to me, "Why was he using a curve in the first place?"

A little exploration in the drawing files revealed the answer—he was tracing, as far as possible, a previous design which originally had to be curved in order to avoid an interference.

Do you think it might be possible to upgrade such men into designers by forbidding them to use tracing paper? Might be worth a try!

—*Cliff*

Multiple-Circuit Switches

Selection and Application of Rotary Switches

By Keith A. Carlson
Assistant Editor, Machine Design

SELECTION and application of multiple-circuit switches is an increasingly important part of machine design. A previous article (MACHINE DESIGN, October, 1954, Page 154) dealt with physical and electrical characteristics of lever-operated switches. Characteristics of rotary switches will be considered in this article. Future articles will cover push or pull types, and the factors to be considered in switch selection.

Of the three primary groups of manually-operated switches, rotary types probably offer highest versatility and current-carrying capacities. Size and weight will, of course, vary with complexity and current-carrying capacity of the switches. However, it should be pointed out that extreme versatility in a small package is offered by rotary switches having low current-carrying capacity.

Rotary switches are of seven basic types:

1. Wafer switches.
2. Drum switches.
3. Tap-changing switches.
4. Face-cam operated switches.
5. Rotary leaf-spring switches.
6. Toggle switches with rotary actuators.
7. Miniature snap-action switches with rotary actuators.

As the names indicate, the last three of these seven types are adaptations of lever or push type switches.

Wafer Switches: Switches of this type, *Fig.* 1, are characterized by their construction from sections referred to as decks, disks or wafers. A single switch assembly may use as many as 12 of these wafers or even more. Another common feature

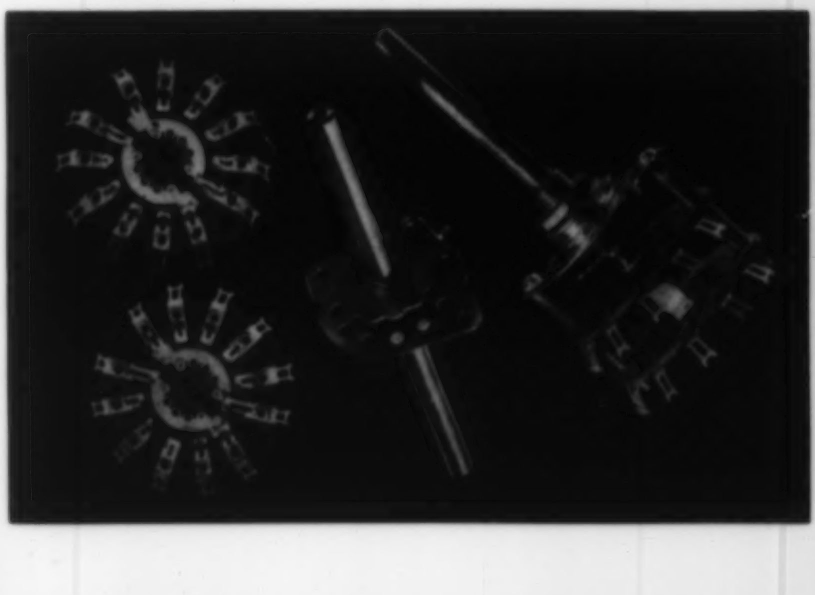


Fig. 1 — Small, two-deck wafer switch is four-pole, five-throw type. Rotating disks with semicircular contact segments are clearly visible on the wafers at left. Shaft and detent mechanism, center, shows holes which serve to position contacts as the operating knob is rotated. Mounting is single-hole type

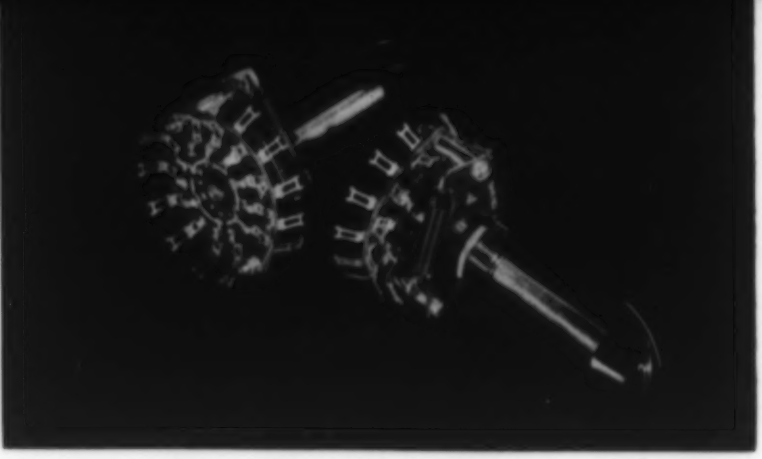
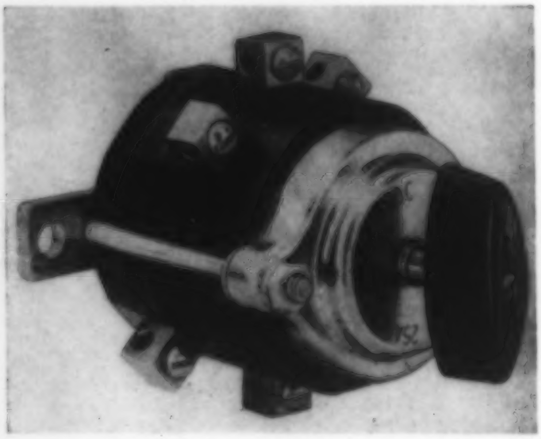


Fig. 3—Above—Spring return to a neutral or "off" position is incorporated in this six-pole, three-throw, single-deck wafer switch

Fig. 2—Below — Rated 25 amperes at 250 volts dc or 500 volts ac, this wafer switch has molded phenolic sections which completely enclose the contact-making moving parts. This switch is intended for base mounting. Similar switches are available for multiple-hole front panel mounting. Phenolic sections are 2¾ inches in diameter. Measurement across wire connectors is 3⅝ inches



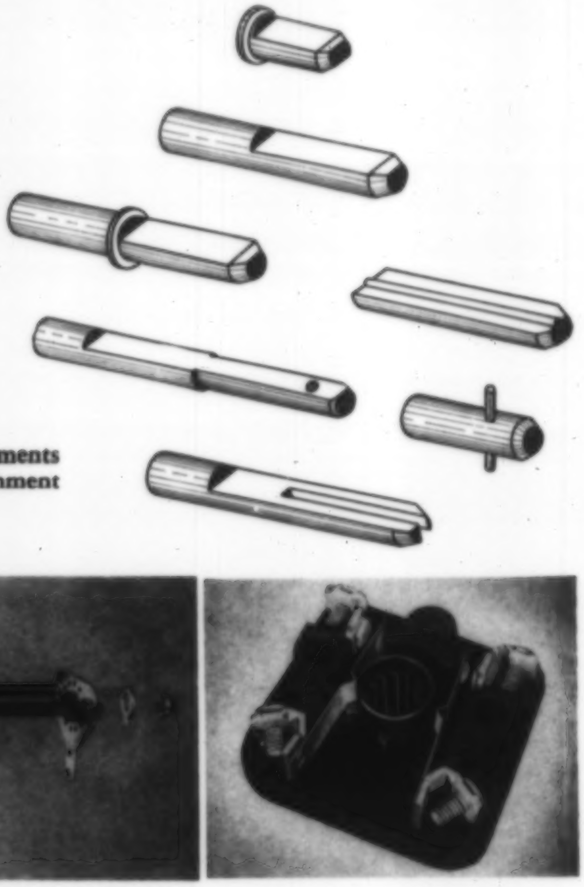
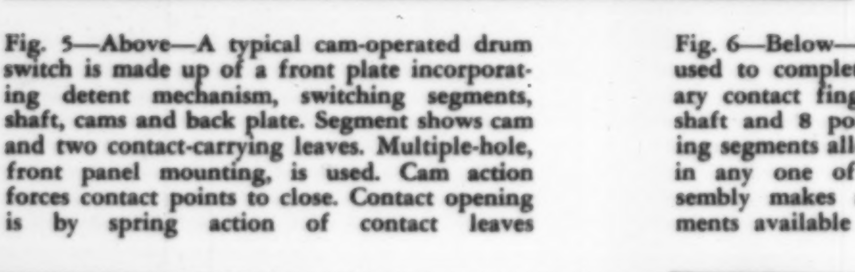


Fig. 4 — Right — Shaft arrangements for rotary switch knob attachment



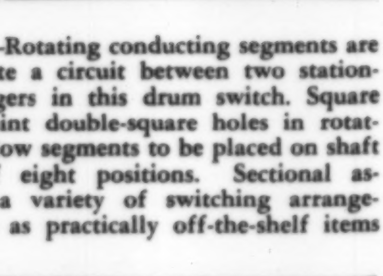
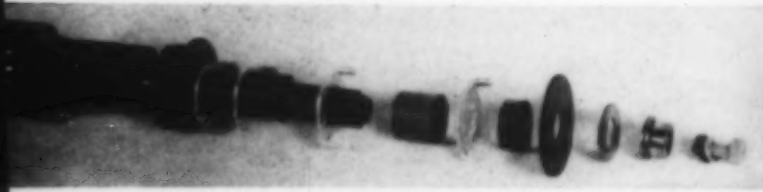
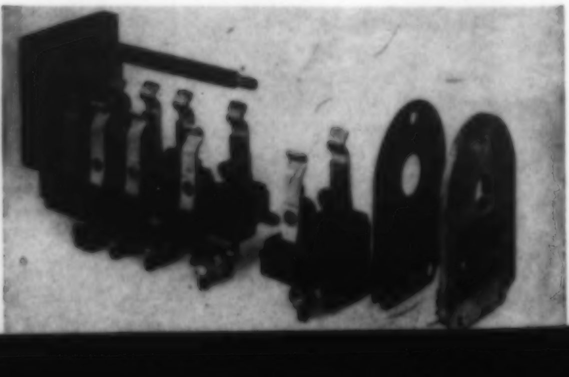


Fig. 5—Above—A typical cam-operated drum switch is made up of a front plate incorporating detent mechanism, switching segments, shaft, cams and back plate. Segment shows cam and two contact-carrying leaves. Multiple-hole, front panel mounting, is used. Cam action forces contact points to close. Contact opening is by spring action of contact leaves

Fig. 6—Below—Rotating conducting segments are used to complete a circuit between two stationary contact fingers in this drum switch. Square shaft and 8 point double-square holes in rotating segments allow segments to be placed on shaft in any one of eight positions. Sectional assembly makes a variety of switching arrangements available as practically off-the-shelf items





is the use of a rotating disk carrying shorting or contact making segments.

Each section of a wafer switch may be thought of as an electrically independent switch physically connected to a number of others by a common shaft. Switching arrangement of a single section may vary from single-pole with as many as 24 positions or throws to nine-pole double-throw. Multiple contacts such as these are usually confined to switches intended for reasonably low current and voltage service.

Current and voltage ratings for wafer switches vary from less than an ampere at a few volts to 500 amperes, 250 volts dc and 600 volts ac. Mounting arrangements vary with size of switches. Smaller sizes usually use the single-hole mounting arrangement; intermediate sizes may use single-hole, base-plate or multiple-hole front mounting; larger sizes usually employ base-plate or multiple-hole front mounting, *Fig*. 2.

Terminals are commonly solder lugs on small wafer switches, with screw type terminals being used on larger switches requiring connections to larger sizes of wire. Low-current switches are usually of quite open construction, *Fig*. 1, and use insulating sections of punched laminated phenolic or molded ceramic materials. Molded phenolic sections are used in wafer switches intended for higher currents, *Fig*. 2, to enclose completely all moving, contact-making parts.

Positive-detent indexing systems are used on wafer switches. Additionally, switches are available using spring and cam operating mechanisms to provide snap-action operation. Another available option on stock switches is spring return to a neutral or "off" position when a two or three-position switch is being used, *Fig*. 3. Both shorting (or make-before-break) and non shorting (or break-before-make) contacts are commonly available.

Operating shaft sizes vary with switch size, ranging usually from ¼ to ⅝-inch. Length is specified by the user and may vary over quite a range. Various types of shaft arrangements for knob attachment are supplied, *Fig*. 4.

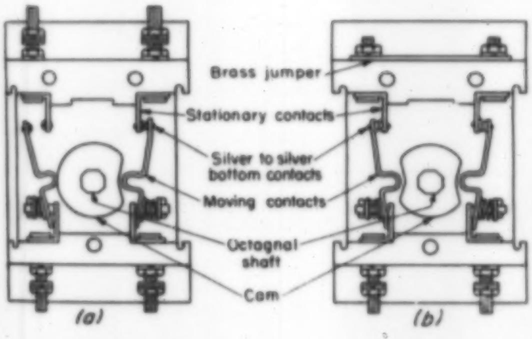
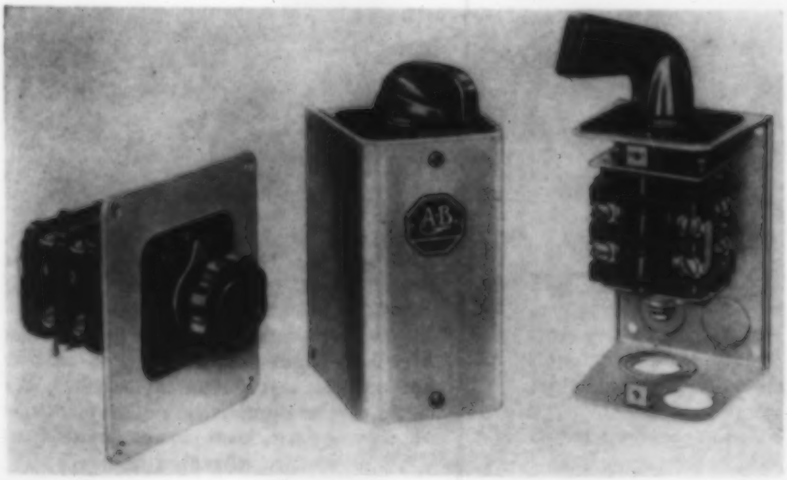


Fig. 7—Single-break, *a*, and double-break arrangement, *b*, of drum-switch contacts. Cam-operated drum switches, as shown, may use either arrangement, since single-break type is easily converted to double-break by use of proper cam and jumper between stationary contacts. Drum switches using rotating conducting segments, *Fig*. 6, are always double-break type because of construction

Fig. 8—Below—Typical arrangements for panel mounting and housing mounting of drum switches. Housing cover is held on by two screws and is easily removable for wiring and inspection. Three of the various types of operating knobs or handles available with drum switches are also shown



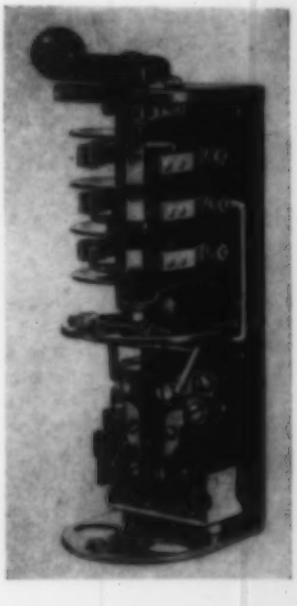


Fig. 9—Thermal overload protection is built into this reversing drum controller for 5-horsepower motors. Available in a sheet-metal enclosure for mounting on a machine, the switch has an overall size of 3⅛ inches square by 10 inches long

Drum Switches: Like wafer switches, drum switches are assembled in sections to provide a complete assembly meeting the designer's specifications. Maximum number of contacts which can be made or broken per section is two. Drum switches or controllers are of two basically different types. One of these types uses cams to open or close contacts on the switch frame, *Fig.* 5. The other uses rotating conducting segments to complete a circuit between contact fingers, *Fig.* 6.

A word of explanation of the terms *drum switch, drum controller* and *master switch* seems to be called for. The three may be identical in construction, operation and current-carrying capacity.

Drum controllers are drum switches with standardized internal contact and wiring arrangements for use as electric-motor controls. They are designed to make and break motor currents and are usually specified in terms of motor service, type and horsepower. A typical specification might call for a reversing, 4-speed, 220-550 volt, 3-phase, 60-cycle, 5-horsepower drum controller for use, of course, with a motor having the same specification. A variety of types are available for use with motors to 10 horsepower.

Table 1—Interrupting Ratings for Drum Switches*

Volts	—Single Break— Inductive Load (amp)	Noninductive Load (amp)	—Double Break— Inductive Load (amp)	Noninductive Load (amp)
Direct Current				
24	15	24	40	50
48	7.5	10	20	25
125	2.0	2.5	7	12
250	0.45	0.5	2	2.25
600	0.12	0.18	0.25	0.3
Alternating Current				
115	30	50	60	80
230	15	25	30	50
440	7	10	15	20
600	2	3	4	6

*For drum switches of *Fig.* 7

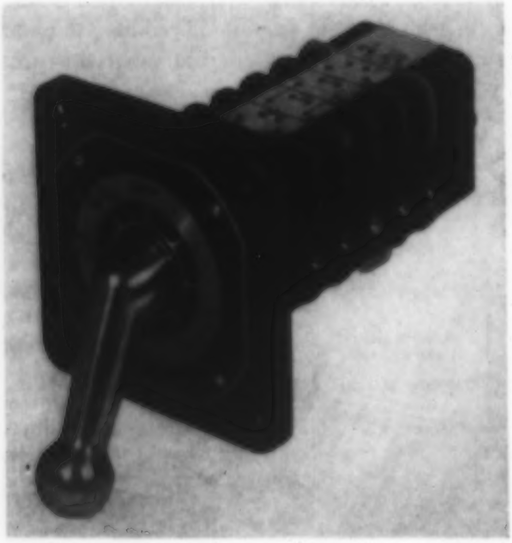
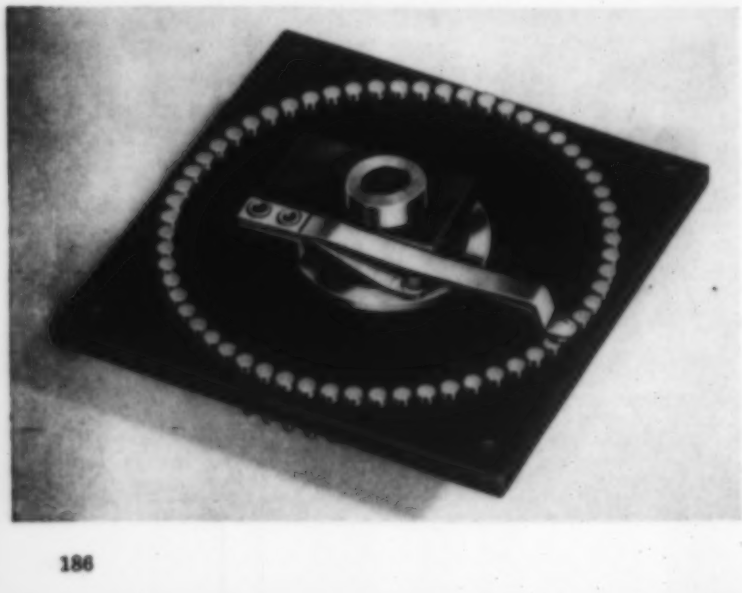


Fig. 10—Right—Circuit selection with this switch is performed while all circuits are disconnected. In order to turn the selector handle, the operator must first push the handle. Integral push-operated contacts disconnect all circuits and the handle can then be turned. When the desired circuit has been selected, the handle is pulled to reconnect the switch

Fig. 11—Below—Tap-changing switch sections usually have a multiplicity of contacts arranged in a circle and connected to a ring by a rotating arm or brush. Section shown has 60 contacts. No detent or positive positioning device is used with many tap changers



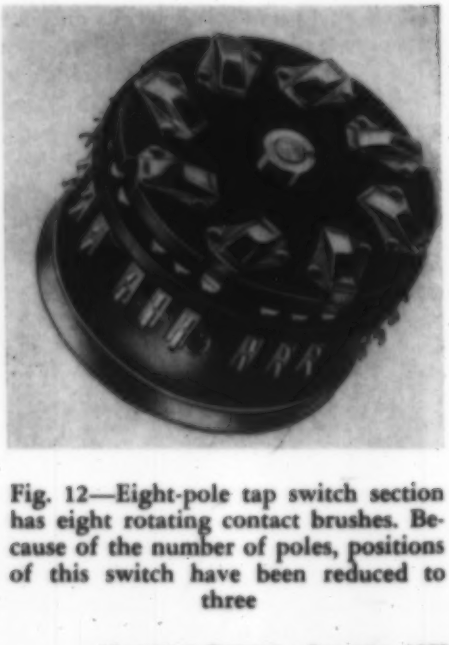


Fig. 12—Eight-pole tap switch section has eight rotating contact brushes. Because of the number of poles, positions of this switch have been reduced to three

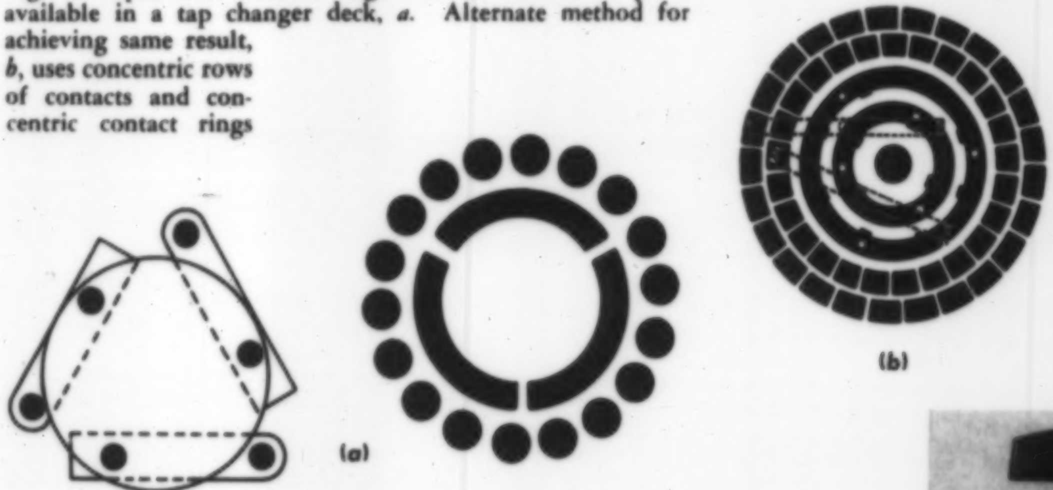
Master switches may be drum controllers used for pilot control of motors, that is to control the opening and closing of relays or magnetic contactors which carry the motor currents. Switch current is, of course, small compared to motor current. However, all master switches are not necessarily drum switches. Any switch used as a pilot or primary control device in this fashion would be a master switch.

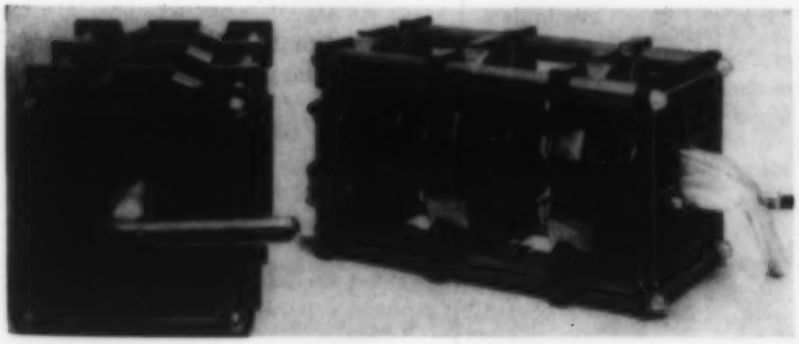
Single or double-break contacts may be used on drum switches, ***Fig.*** 7. As these terms suggest, a single set of contacts interrupts a circuit with single-break construction, while two separate contact points are used to interrupt a single circuit equal, a switch using single-break contacts offers in the double-break type. All other things being higher versatility. Double-break contacts allow higher interrupting ratings, ***Table*** 1, and longer contact point life.

A great variety of standard cams for use in drum switches are usually produced by individual manufacturers. This variety of cams, combined with square, 8-point double-square or octagonal shafts often used, and a multiplicity of switch sections, results in a quite versatile selection of switches.

Mounting may be multiple-hole panel mounting, or drum switches may be supplied in housings for attachment to machines, ***Fig.*** 8. These housings or enclosures are available in drip-proof, water or oil-tight, dust-tight and explosionproof varieties. Auxiliary switching and control devices such as thermal overloads for motors may also be assem-

Fig. 13—Split-rotor contact rings increase number of poles available in a tap changer deck, *a*. Alternate method for achieving same result, *b*, uses concentric rows of contacts and concentric contact rings





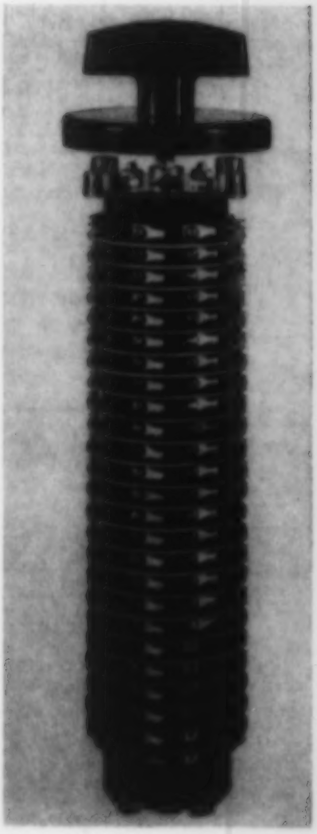


Fig. 14—Above—Heavy-duty tap switch uses multiple-leaf stationary and rotating contacts to carry extremely high currents. Switches of the type shown may carry currents of more than 1000 amperes, which is well above currents commonly used in machine control

Fig. 15—Twenty-five sections are used in this 25-pole, 8-throw switch having positive detent action. Switch is 3¼ inches in diameter and is 11 7/16 inches deep behind the mounting panel. Mounting is multiple-hole type

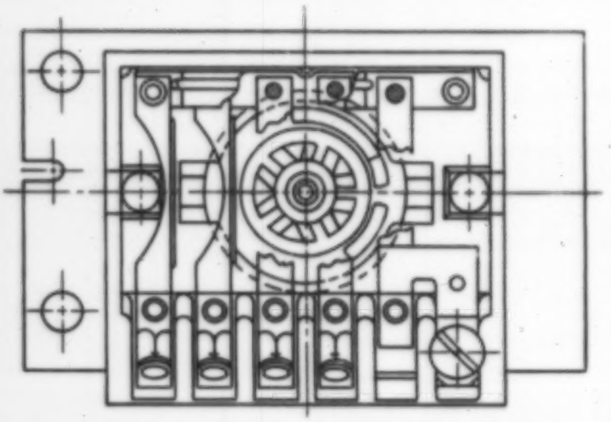


Fig. 16 — Above — Face-cam operated switch measures 2 15/32 by 2 13/64 by 57/64-inch. Contact leaves have been removed to permit seeing the two concentric cams

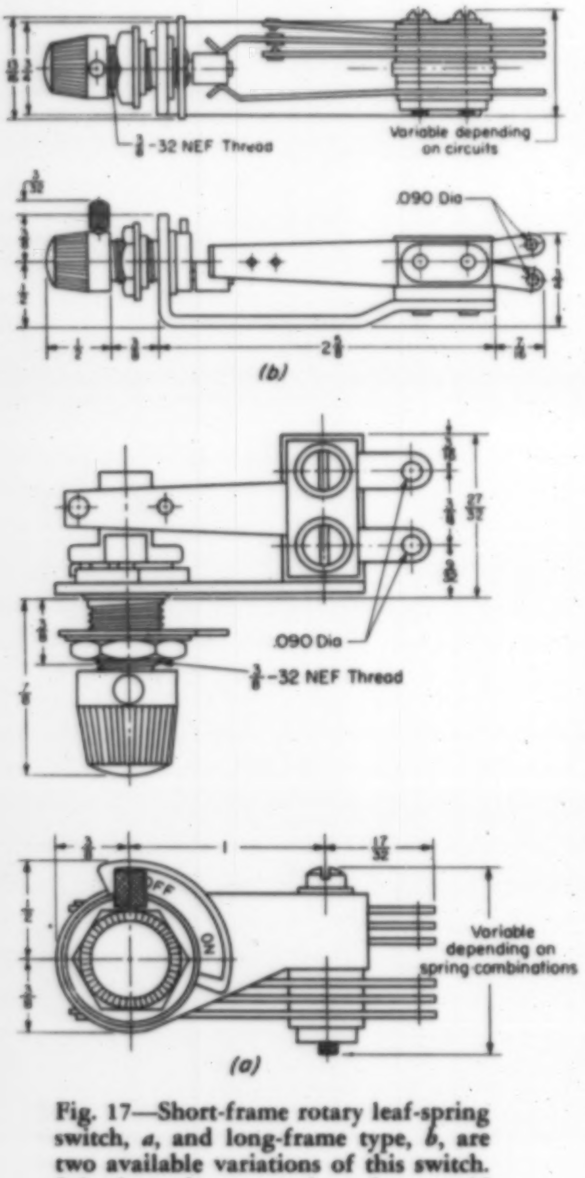


Fig. 17—Short-frame rotary leaf-spring switch, *a*, and long-frame type, *b*, are two available variations of this switch. Selection of one or the other would be dictated primarily by space requirements

bled into the housings by the switch manufacturer, *Fig.* 9.

Operating cams or mechanisms are usually designed to give quick opening and closing of contact points. Positive positioning by detents is another feature of drum switches. Automatic spring return to an "off" position is an option usually available. Other interesting variations in drum switch construction are incorporation of "push" or "pull" operated contacts, *Fig.* 10, and mechanical time delay. Mechanical construction of switches with the time delay mentioned prevents the operator from rotating the switch past a given contact position without first momentarily releasing and then re-applying the pressure producing the desired rotation.

Tap-Changing Switches: Distinguishing feature of the tap-changing switch, tap switch or tap changer as it may be called, is the use of a rotating contact arm or brush which makes contact with a series of stationary contacts as the operating knob is rotated, *Fig.* 11. A wiper or slip ring is used to connect the rotating arm to a terminal. As many as 60 contacts have been used on single section tap switch to produce a single-pole, 60-throw switch. Sections may, of course, be "ganged" to produce even more versatile switches.

Although individual decks of a tap switch are usually of single-pole, multiple-throw construction, they are sometimes constructed to give up to eight-pole switching, *Fig.* 12. This can be done by splitting the rotor-blade contact ring or by using concentric rings and contact rows, *Fig.* 13.

Contacts of tap switches are usually of silver or silver alloys, or are available with silver plating. Low contact resistance and long life result. Switches for any voltage or current to be found in the field of machine control are available, *Fig.* 14. Current-carrying capacities of the majority of these switches far exceed their interrupting capacity because of the relatively slow breaking of the contact points. However, fast break types are available.

Mechanical stops or detents to position the brush or rotor of a tap switch may or may not be a part of the switch assembly, *Fig.* 15. Both shorting and nonshorting types are available. As with other rotary switch types, a variety of operating knobs are available. Panel mounting, either single or multiple-hole type, may be used.

Face-Cam Operated Switches: So called because the operating cams are on the face of a rotating disk, switches of this type are used primarily in home-appliance control applications. Usually built to order for use in high-production items, these switches offer many interesting switching arrangements. However, an extreme multiplicity of circuits may not be controlled with these switches. Two or three circuits are the maximum.

One interesting example of this type of switch, *Fig.* 16, uses two concentric face cams to open or close three contacts mounted on leaves. A ratchet is used to drive the inner of the two cams and thereby close a different contact each time the switch shaft is turned from the counterclockwise to the clockwise position. This might be considered the equivalent of a three-position switch.

Cam contours and overcenter springs against which the shaft must be rotated impart fairly rapid opening and closing times to these switches although not as rapid as the snap-action types. Typical contact rating is 10 amp at 250 v ac or ½-hp at 125 or 250 v ac.

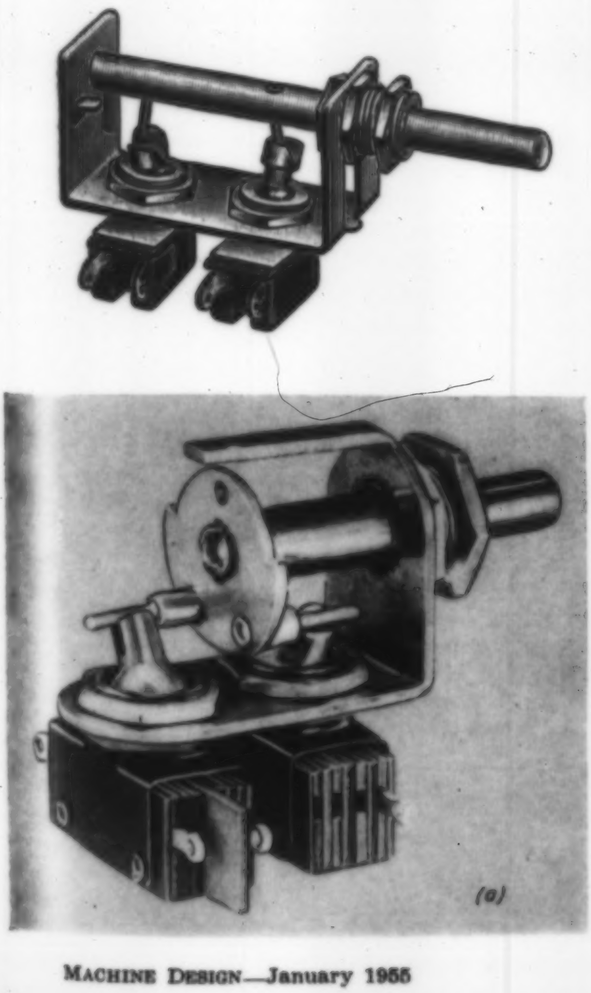
Rotary Leaf-Spring Switches: Basic construction, contact ratings and size of these switches are as described in a previous article on lever-operated switches (MACHINE DESIGN, Oct., 1954, Page 154). Number of leaf buildups which may be combined in one assembly is somewhat limited, compared to the lever types. Most complex switching arrangements readily available are four sets of form A or form F contacts.

Mounting may be single or multiple-hole type. Two or three-position types are available with detents in all positions or automatic return to a desired neutral or "off" position. Operating knobs may be at right angles to the axis of the leaves or in line with the leaves, *Fig.* 17.

Toggle Switches with Rotary Actuators: Adapters for rotary operation of toggle switches, *Fig.* 18, are available from manufacturers of these switches. Resulting assemblies are more versatile than an individual switch and at the same time retain other desirable properties of toggle switches such as small size, low weight, relatively low cost, snap action and fairly high current-carrying capacity.

Snap-Action Switches with Rotary Actuators: As many as eight small snap-action push-type switches have been combined into switch assemblies actuated by rotating cams, *Fig.* 19. Various cam contours and relationships can be used to produce a multiplicity of switching arrangements. A detent mechanism is incorporated into the assembly to provide a positive stop at each switch position. Positions range from two to eight as desired.

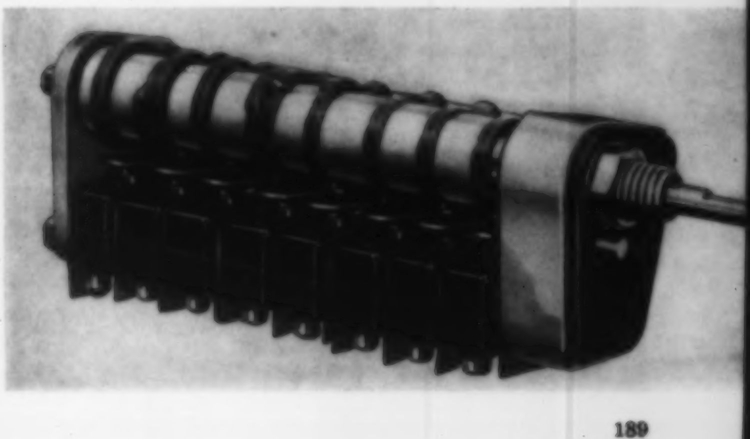
Fig. 18—Two variations of rotary actuators available for use with toggle switches are shown here. Types are available which require no modification of the toggle levers

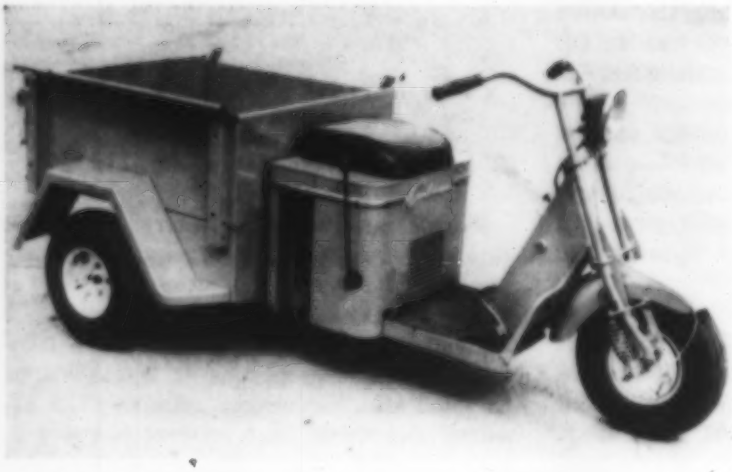


CREDITS

Figs. 1, 3	Centralab Div., Globe Union Inc., Milwaukee 1, Wis.
Figs. 2, 10	Arrow-Hart & Hegeman Electric Co., Hartford 6, Conn.
Figs. 4, 16	Soreng Products Corp., Schiller Park, Ill.
Figs. 5, 8	Allen-Bradley Co., Milwaukee 4, Wis.
Fig. 6	Allis-Chalmers Mfg. Co., Milwaukee 1, Wis.
Fig. 7, *Table* 1	Roller-Smith Corp., Bethlehem, Pa.
Fig. 9	Furnas Electric Co., Batavia, Ill.
Figs. 11, 13a	Shallcross Mfg. Co., Collingdale, Pa.
Fig. 12	Daven Co., Newark 4, N. J.
Fig. 13b	Industrial Div., Minneapolis-Honeywell Regulator Co., Philadelphia 44, Pa.
Fig. 14	Barksdale Electric Mfg. Co., Middletown, O.
Fig. 15	Electro Switch Corp., Weymouth, Mass.
Fig. 17	Carter Parts Co., Chicago, Ill.
Fig. 18	Arrow-Hart & Hegeman Electric Co., Hartford 6, Mass. and Carling Electric Inc., West Hartford 10, Conn.
Fig. 19	Micro Switch Div., Minneapolis-Honeywell Regulator Co., Freeport, Ill.

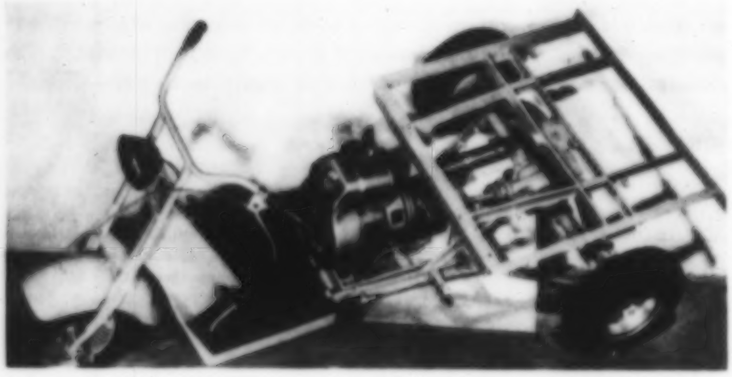
Fig. 19—Eight small single-pole double-throw snap-action switches are used in this assembly. Designed for single-hole mounting, the switch measures 1⅛ inch high, 29/32-inch wide and extends 2 25/32 inches behind the mounting panel. Basic switches are rated 5 ampere at 125 or 250 volts ac. Similar units using larger basic switches are also available



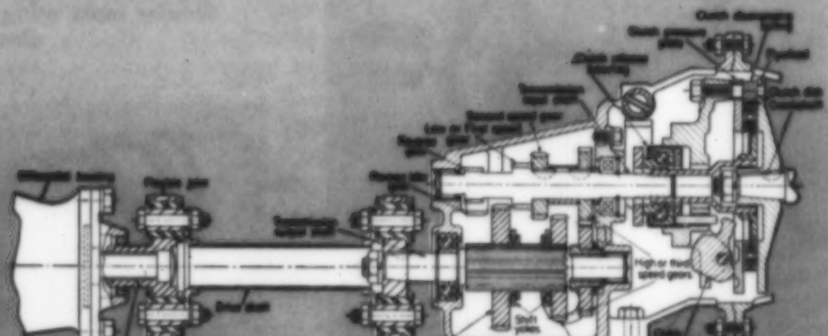


COMBINING many of the features of a full-size automotive vehicle with those of a motor scooter, the Cushman 780 Truckster has high load-carrying capacity, low weight and excellent fuel economy. A 5-hp air-cooled gasoline engine drives the Truckster at speeds up to 35 mph with a fuel consumption rate of 50 miles per gallon. The steel pickup box provides nearly 10 cubic feet of carrying capacity for loads to 500 pounds. Empty weight is only 525 pounds.

Motor Scooter-Truck Uses Automotive Drive Train



Power train components are clearly shown when pickup box and the combination engine enclosure and operator's seat are removed. Power from the engine is transmitted by a single disk clutch which disengages automatically at low engine speeds and is pedal-operated when shifting gears with the vehicle in motion. A selective sliding-gear type transmission attached to the rear of the clutch housing provides three speeds forward and one reverse. Transmission output shaft is connected to an automotive type differential and rear axle by a drive shaft with two universal joints. Brakes are fitted to all three wheels. Rear wheel brakes are pedal-operated in automotive fashion while the front wheel brake is controlled by the grip lever shown on the handle bar.


Differential housing
Drive shaft
Transmission output shaft
High or third speed gears
Shift yokes
Second and third sliding gear

Automatic clutch disengagement at low speeds is effected by three disengaging springs which separate flywheel and pressure plate and prevent their clamping the clutch disk. At higher engine speeds, centrifugal force causes release levers to pivot on their pins and force pressure plate, disk and flywheel into contact. Shifter yokes slide one or the other of the sliding gears along the splined transmission output shaft to select the desired transmission ratio.

HYDRAULIC SERVO-VALVE DESIGN

For small input signals, a two-stage valve provides preamplification for movement of the main valve spool. This article discusses practical design factors for optimum control performance.

By J. M. Nightingale
Manchester, England

SMALL hydraulic valves for sensitive servos in the fields of military armament and industrial controls have received considerable attention in recent years. In particular very high-gain valves are required in some applications such as guided weapons where only low-power electrical signals are available to operate the valves. This article discusses some theoretical and practical aspects of a particular type of small hydraulic servo valve.

Cylindrical type slide valves are the most common hydraulic selectors used in servo applications. Although these are theoretically force-balanced, friction and hydrodynamic forces on the valve are such that large loads must be overcome to operate the valve. These loads can be of the order of several pounds for quite small valves, and often they exceed the force available to operate the valve.

A great deal of experimental and theoretical investigation of axial valve forces has been carried out, and results have been collected and summarized by Hadekel*. From this work it can be concluded that much can be done to reduce operating loads by intelligent design but, of course, there is a limit to what may be achieved in this manner. Where the load exceeds the force available to displace the valve, it is necessary to add a preamplifier, usually a small hydraulic pilot valve, between the input and the main valve. The combined unit is called a two-stage control valve.

Many types of small two-stage valves have been developed. Some of them are ingenious in design, but most of the designs are variations of certain basic types which differ in construction rather than principle. A quite common type of valve is one in which a controlled leak is used to build up a pressure which, when applied on one end of the main valve spool, can exert a force considerably

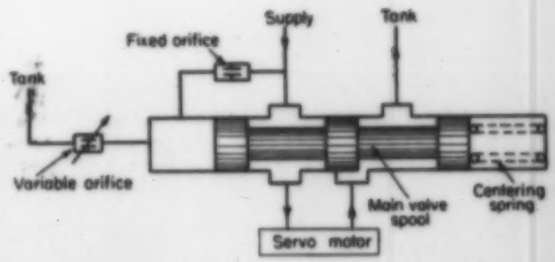


Fig. 1—Servo valve with leakage control provided by two orifice type restrictors. Main valve spool position is controlled by variable orifice

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*R. Hadekel—*Characteristics and Design of Hydraulic Valves for Sensitive Servomechanisms*, British Messier Ltd., 1952.

greater than the opposing valve forces. This type of device is shown diagrammatically in *Fig.* 1, and it is a variant of this which forms the subject of this article.

Valve Design: The operating principles of the unit shown in *Fig.* 1 are simple. A small leakage flow is taken from the supply and is passed through two restrictors. The second restrictor is variable and is used to control the pressure in the chamber at the end of the valve spool. The pressure force on the spool is opposed by a centering spring so that a proportional valve displacement and therefore a roughly proportional flow are obtained. Thus, varying the restriction according to the servo error achieves considerable power amplification. The two-stage valve is in fact an open-loop amplifier.

The pilot valve is actually the variable orifice in *Fig.* 1. It may be either a balanced slide valve, a smaller version of the main valve, or it may be a seating valve of the flapper-nozzle type. The pilot valve is operated by a transducer which converts an electrical signal into a mechanical force. In missile applications, for example, transducers generally consist of moving coil relays capable of exerting forces of several ounces.

Flapper-nozzle valves are particularly suitable as pilot valves since the transducer force can be used directly instead of first being converted into a proportional pilot valve displacement. This latter type of unit will be generally discussed and analyzed in the remainder of this article. A diagram of the complete unit including the transducer is shown in *Fig.* 2.

Nomenclature

A = Cross-sectional area of slide valve spool, sq in.
D_o = Diameter of nozzle, in.
D_s = Diameter of fixed orifice, in.
F_o = Centering spring force when valve is in neutral position, lb
H = Power loss at nozzle, lb-in. per second
K_1 = Stiffness of centering spring, lb per in.
K_2 = Stiffness of flapper, lb per in.
P_i = Input signal as equivalent chamber pressure, psi
P_o = Chamber pressure, psi
P_s = Supply pressure, psi
Q_l = Neutral leakage flow from nozzle, cu in. per second
Q_o = Flow through nozzle, cu in. per second
Q_s = Flow through fixed orifice, cu in. per second
R = Ratio of orifice areas
= $(D_o/D_s)^2$
T = Equivalent time constant for valve, seconds
T_o = Operating time for full valve stroke, seconds
X = Valve spool displacement from neutral, in.
X_i = Input signal as equivalent spool displacement, in.
X_m = Amplitude of spool response displacement, in.
X_o = Amplitude of first harmonic of spool response, in.
X_s = Maximum valve spool displacement from neutral, in.
Y = Displacement of flapper from seat, in.
ϕ = Phase lag of spool response, radians
ω = Frequency of input signal, radians per second

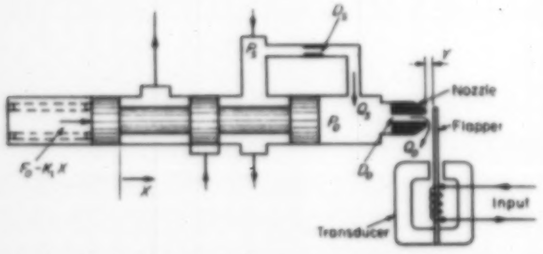


Fig. 2—Complete two-stage hydraulic servo valve including transducer. Flapper-nozzle seating valve controls leakage flow

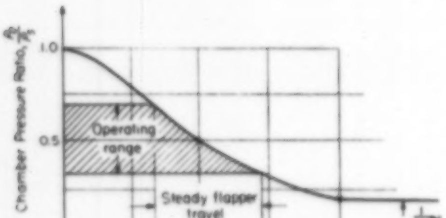


Fig. 3—Nondimensional graph of chamber pressure versus flapper displacement

For chamber pressure to be independent of supply pressure and depend only on transducer force, the flapper which is carried by the transducer armature must be without spring rate. In an ingenious valve developed by Cornell Research Laboratories, this design requirement was achieved by balancing the spring rate of the flapper (positive) against the gradient of the magnetic force (negative) developed by the transducer. The stability of the flapper, and therefore of the valve, is so critical near balance that it is necessary to have a very slight positive rate.

Steady-State Conditions: Under steady-state conditions the chamber pressure P_o is equal to the pressure equivalent of the input signal, P_i. The pressure P_i is equal to the force developed at the nozzle by the transducer divided by the throat area of the nozzle. Since the flapper has zero or very low rate, it can take up a position to allow equal flow through the nozzle and the inlet orifice. The flow through the inlet orifice is given by

$$Q_s = 80\, D_s^2 \sqrt{P_s - P_o} \qquad (1)$$

There are two relations for the flow through the nozzle. The first gives the flow when the restriction is caused by the flapper, and the second gives the flow when the flapper has moved away from the nozzle with flow being restricted by the throat area of the nozzle. The flow equation for the first condition is

$$Q_o = 400\ D_o\ Y\ \sqrt{P_o} \qquad (2)$$

where $Y < D_o/5$ and for the second condition the flow is

$$Q_o = 80\ D_o^2\ \sqrt{P_o} \qquad (3)$$

for $Y > D_o/5$. The formulas in the preceding equations hold only for English units and are based on a specific gravity of 0.85 and a discharge coefficient of 0.65 for circular orifices and 0.80 for annular orifices.

Equations 1, 2 and 3 are based on Bernoulli's equation for steady flow of a nonviscous incompressible fluid. Recent investigations show that for small orifices the flow depends not only on the orifice area and the pressure drop, but also on viscosity, orifice shape and time. For small orifices appreciable time passes before steady conditions are reached. However, the errors incurred by the initial assumption may not be as large as other errors in design quantities.

From Equations 1 and 2, an expression can be obtained for the steady-state chamber pressure in terms of the flapper displacement:

$$P_c = \frac{P_s}{1 + 25\left(\frac{RY}{D_o}\right)^2} \qquad (4)$$

A graph of chamber pressure versus flapper displacement is shown in *Fig.* 3. For $Y > D_o/5$ the chamber pressure remains constant at $P_s/(1 + R^2)$. If the equivalent input pressure falls below this value, the flapper will move right away to the end of its travel, since it has no spring rate. In practice it is usual to limit the flapper stroke to slightly more than $D_o/5$ to avoid unnecessary time lags and to limit flapper inertia effects.

A mean chamber pressure must be chosen that corresponds to the neutral position of the valve spool. Similarly two extreme chamber pressures must be selected that correspond to the two extremes of spool travel. In order to limit the steady-state flapper travel, the range of chamber pressures is kept small. For this reason the mean pressure is chosen on the steepest part of the curve in *Fig.* 3. It is convenient to choose a mean chamber pressure of $P_s/2$, and an operating range extending from $0.3P_s$ to $0.7P_s$. Then the total force available to maintain full valve displacement is $\pm\ 0.2AP_s$.

There are several reasons for keeping the steady flapper travel small. One important reason is to prevent spreading of the jet leaving the nozzle, since this can cause a gradient (negative) in the hydrodynamic force on the flapper. Since the flapper is usually balanced in the absence of flow.

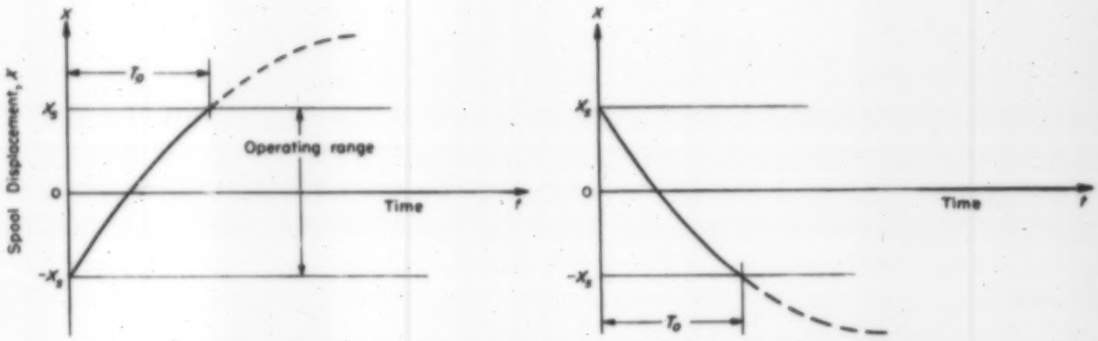


Fig. 4—Valve spool displacement over full stroke in either direction

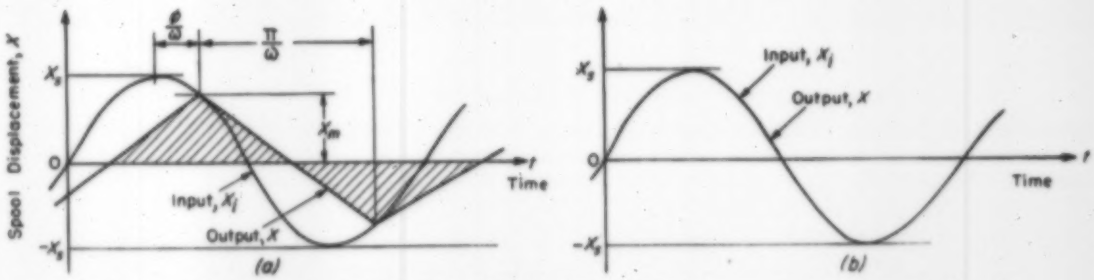


Fig. 5—Valve spool displacement for high frequencies, *a*, and low frequencies, *b*

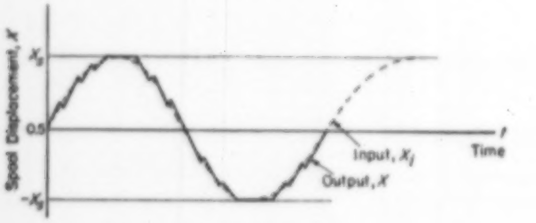


Fig. 6—Displacement curve of valve spool showing jerking motion caused by its inertia and friction

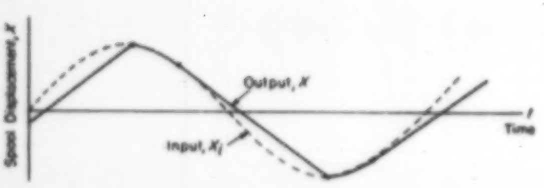


Fig. 7—Transitional response between triangular and sinusoidal waveform

it may have a slightly negative rate under operating conditions, which may cause instability.

Another reason for short flapper travel is that the magnetic force developed by the transducer varies with the inverse square of flapper distance from the mean position. The magnetic rate is only constant for small displacements about the mean position. Due to nonlinearities, rate balancing is difficult to achieve, and for large travels the flapper may become slightly unbalanced with a negative stiffness. This leads to instability and loss of proportionality between the input and the steady valve displacement.

By substituting from Equation 4 into Equation 3, an expression for the steady flow loss from the valve can be obtained:

$$Q_o = \frac{400\, D_o\, Y\, \sqrt{P_s}}{\sqrt{1 + 25\left(\frac{RY}{D_o}\right)^2}} \qquad (5)$$

When the mean chamber pressure is $P_s/2$, the flapper displacement value of $Y = D_s^2/5D_o$ so that the neutral leak from the nozzle is

$$Q_l = 80\, D_s^2 \sqrt{\frac{P_s}{2}} \qquad (6)$$

Of course, this relation could have been obtained by considering the flow through the inlet orifice under the same condition.

The steady power loss at the nozzle in the neutral position is given by

$$H = \frac{Q_l\, P_s}{2} = 80\, D_s^2 \sqrt{\left(\frac{P_s}{2}\right)^3} \qquad (7)$$

Dynamic Characteristics: Before attempting to analyze the dynamic performance of the valve, it is necessary to examine in detail the mechanism by which the main valve spool position is controlled.

Under dynamic conditions the transducer generates a varying force on the flapper which either opens or seals the nozzle. This destroys the flow equilibrium of the two orifices, and the excess flow displaces the valve spool. The spool is then moved against the centering spring until the chamber pressure again balances the input. There is a limit to the speed at which the spool can be displaced, and therefore the chamber pressure may lag the input pressure. Since the flapper will have little or no stiffness, in this case it will move almost instantaneously to its extreme position and will either completely seal or open the nozzle on successive half-cycles. For the extreme flapper positions, there are saturated spool velocities in either direction, and the following analysis shows how these velocities determine the response characteristics of the valve.

Consider first the case when the net flapper force, $\pi D_o^2(P_i - P_o)/4$, acts toward the nozzle. The flapper virtually seals the nozzle, and the total flow from the inlet orifice displaces the valve. The flow equation in this case is

$$Q_s + A\frac{dX}{dt} = 0 \qquad (8)$$

This defines spool motion from $+X_s$ *to* $-X_s$. Motion in the other direction is given by

$$Q_s + A\frac{dX}{dt} = Q_o \qquad (9)$$

where Q_o is given by Equation 3.

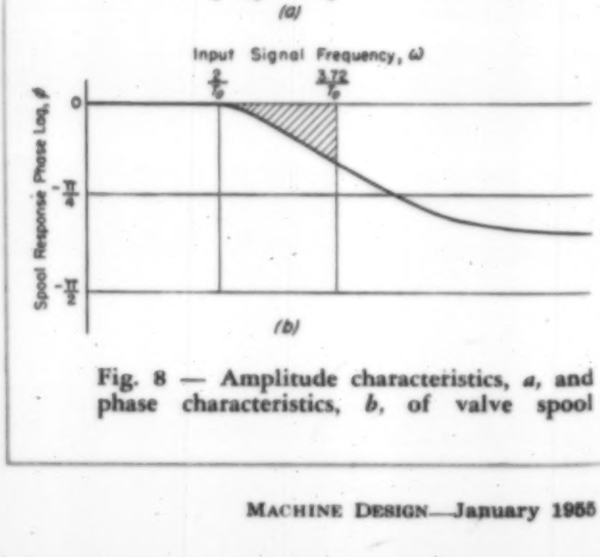


Fig. 8 — Amplitude characteristics, *a*, and phase characteristics, *b*, of valve spool

Equating the forces on the valve spool, neglecting friction,

$$A\,P_o = F_o - K_1 X \tag{10}$$

Substituting in Equations 1 and 3 and taking the mean chamber pressure to be equal to $P_s/2$,

$$Q_s = Q_l \sqrt{1 + \frac{2\,K_1\,X}{A\,P_s}} \tag{11}$$

and

$$Q_o = Q_l\,R \sqrt{1 - \frac{2\,K_1\,X}{A\,P_s}} \tag{12}$$

From Equations 8, 9, 11 and 12 expressions can be obtained for the time to travel full stroke, $2X_s$, in either direction:

$$T_o = \frac{A}{Q_l} \int_{-X_s}^{X_s} \frac{dX}{\sqrt{1 + \frac{2\,K_1\,X}{A\,P_s}}} \tag{13a}$$

for the right to left direction, and

$$T_o = \frac{A}{Q_l} \times \int_{-X_s}^{X_s} \frac{d\,X}{R\sqrt{1 - \frac{2\,K_1\,X}{A\,P_s}} - \sqrt{1 + \frac{2\,K_1\,X}{A\,P_s}}} \tag{13b}$$

for the left to right direction. The integrals in Equations 13*a* and 13*b* are rather laborious to evaluate completely, especially the latter. However, if only a limited chamber pressure range is taken, then both equations can be simplified by the binomial expansion. If it is assumed here that the range of P_o extends from $0.3P_s$ to $0.7P_s$, Equation 13*a* results in

$$T_o = \frac{5\,A\,X_s}{Q_l} \int_{-X_s}^{X_s} \frac{d\,X}{5\,X_s + X}$$

$$= \frac{5\,A\,X_s}{Q_l} \log_e \left(\frac{3}{2}\right) = \frac{2.03\,A\,X_s}{Q_l} \tag{14a}$$

and Equation 13*b* reduces to

$$T_o = \frac{5\,A\,X_s}{Q_l} \int_{-X_s}^{X_s} \frac{d\,X}{5\,X_s\,(R-1) - X\,(R+1)}$$

$$= \frac{5\,A\,X_s}{Q_l\,(R+1)} \log_e \left(\frac{3\,R-2}{2\,R-3}\right) \tag{14b}$$

The obvious requirement that these two periods of time be equal yields

$$\frac{3\,R-2}{2\,R-3} = \left(\frac{3}{2}\right)^{R+1} \tag{15}$$

The numerical solution of Equation 15 is R = 2.16. This result shows that nozzle throat area must be slightly more than twice the area of the inlet orifice. Valve displacements in either direction are plotted against time in *Fig.* 4. The dotted extension of these curves shows that if the range of chamber pressures is large, considerable time lags are introduced in the spool motion. This is accentuated by nonlinearity in the flow equations. With the limited range considered here, the saturated spool velocity can be considered as constant and equal to $2X_s/T_o$ in each direction.

The response characteristic of the valve is of prime interest to the designer. To examine this factor it is convenient to represent the input signal by an equivalent spool displacement, X_i. This may be done by defining X_i by an equation similar to Equation 10, or

$$A\,P_i = F_o - K_1\,X_i \tag{16}$$

It is apparent from Equation 10 and 16 that if $X_i > X$, the nozzle is open. Also the motion of the main valve is from left to right. If $X_i < X$, the main valve motion is in the opposite direction.

Spool response will be considered to be an input of the form $X_i = X_s \sin \omega t$, that is, a sinusoidal demand for full travel. There are two distinct types of response and these are shown in *Fig.* 5. The first of these, *Fig.* 5*a*, occurs above a certain frequency. In this case the input varies more rapidly than the spool is able to follow, and so the output lags the input. The output catches the input when it has returned to a value X_m which is less than the maximum travel X_s; at this point the flapper moves to its other extreme, and the spool velocity is reversed. The condition for a waveform of the type shown in *Fig.* 5*a* is that

$$\left|\frac{dX}{dt}\right| = \frac{2\,X_s}{T_o} < \left|\frac{dX_i}{dt}\right| \tag{17}$$

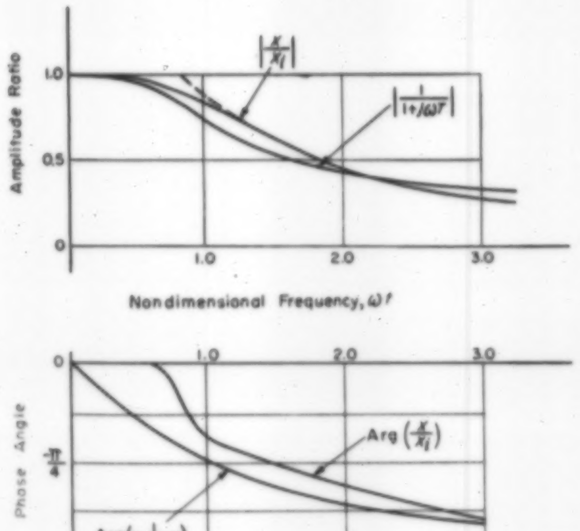


Fig. 9 — Response characteristics of valve compared with equivalent transfer function having single time constant

when $X = X_i = X_m$. This condition is given by

$$\omega > \frac{3.72}{T_o} \tag{18}$$

Therefore, for frequencies above $3.72/T_o$ the valve response has a triangular waveform, and the greatest displacement is

$$X_m = \frac{\pi X_s}{\omega T_o} \tag{19}$$

It is not strictly correct to speak of an amplitude ratio and a phase angle for a nonharmonic response; however, if only the first harmonic is considered, these terms may be defined with sufficient accuracy for most purposes by

$$\left| \frac{X}{X_i} \right| \approx \frac{X_o}{X_s} = \frac{0.812\, X_m}{X_s} = \frac{2.55}{\omega T_o} \tag{20}$$

$$\text{Argument} \left(\frac{X}{X_i} \right) = \varphi = \cos^{-1} \left(\frac{\pi}{\omega T_o} \right) \tag{21}$$

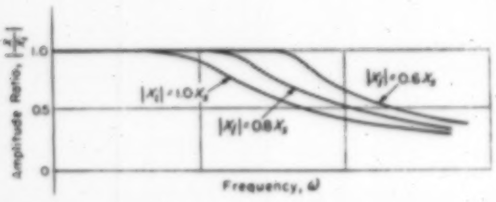


Fig. 10 — Variation of valve response versus input amplitude

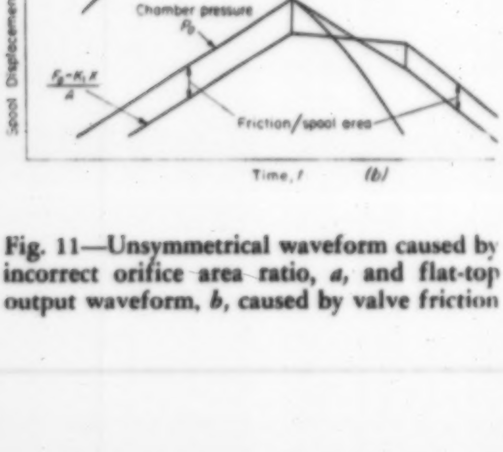


Fig. 11—Unsymmetrical waveform caused by incorrect orifice area ratio, *a*, and flat-top output waveform, *b*, caused by valve friction

The second type of response is shown in *Fig.* 5*b*. Here the output is a faithful reproduction of the input, if dX_i/dt is always less than $2X_s/T_o$. For this condition,

$$\omega < \frac{2}{T_o} \tag{22}$$

In practice the smooth type of output curve shown in *Fig.* 5*b* is seldom achieved since valve inertia and friction combine to produce the slightly jerking motion shown in *Fig.* 6.

For frequencies between those given by Equations 16 and 21 the spool response takes neither of the two distinct forms, but it is a combination of the two as depicted in *Fig.* 7. Curves of amplitude ratio and phase angle are shown in *Fig.* 8. The cut-off frequency occurs at $\omega = 2.55/T_o$; this might be expected since this frequency is slightly less than the highest frequency at which full spool displacement could be obtained under saturated conditions.

The response characteristics of the valve are similar to those of a simple transfer function with a single time lag. In assessing the overall servo performance it is convenient to represent the valve by a transfer function of the form $K/(1 + j\omega T)$ where T is the equivalent time constant of the valve, and K is the gain of the complete valve including the transducer. The term K gives the relation between the steady-state electrical input to the transducer and the steady-state spool displacement.

The equivalent time constant is given approximately by

$$T = \frac{T_o}{2.8} = \frac{A X_s}{78 D_s^2 \sqrt{P_s}} \tag{23}$$

In *Fig.* 9 actual response curves for the valve are compared with those of the assumed transfer function. In general the amplitude characteristics are slightly better for the assumed curve and the phase lag is slightly worse. As long as the stability of the servo is not critical, this is unimportant, since amplitude relations are more important than phase lags.

So far it has been assumed that the input demand has corresponded to full displacement of the valve. However, for smaller inputs the response characteristics improve, and the frequency scale in *Fig.* 9 is increased in the ratio of the maximum valve displacement divided by the input amplitude. The effect of input amplitude on response is shown in *Fig.* 10. For very small input signals the response is swamped by friction forces and tends to deteriorate rather than improve.

Experimental Observations: Although the preceding theory has been idealized by the assumptions made, test results have shown good agreement. In particular the amplitude ratio has been found to be constant up to the cut-off frequency with no attenuation at all. Then cut-off is severe instead of the gradual attenuation of the assumed transfer function. Experiment also confirms that improved performance can only be bought at the cost of increased flow and power losses at the nozzle.

The ratio of orifice areas has been found to be very important; if this is wrong, a lopsided waveform is obtained, *Fig.* 11*a*. The value of R predicted here has generally proved satisfactory.

Valve spool inertia effects are not serious, since the spool can be made so light that its natural frequency on the centering spring is perhaps ten times as high as the frequency range of the valve.

Valve spool friction can cause the output waveform to be slightly flat-topped, *Fig.* 11*b*.

A major source of trouble is flapper instability, and this can cause considerable roughness in the response of both the valve and the servo as a whole. Flapper oscillations are triggered by surges in the pressure supply.

Flapper instability is associated with the flapper rate K_2. For small disturbances x, y, p_o and p_s in the steady-state variables X, Y, P_o and P_s about the neutral position,

$$-p_s = \left(\frac{1.2\,\pi\,R D_o\,P_s\,K_1}{A\,K_2} \right) x + \left(\frac{A\,P_s}{Q_l} \right) \frac{dx}{dt} \qquad (24)$$

Thus for a stable valve the flapper stiffness cannot be negative. Since balance is rather critical, a small positive rate should be provided.

The steady-state valve displacement for a steady variation in supply pressure is

$$x = -p_s \left(\frac{A\,K_2}{1.2\,\pi\,R D_o\,P_s\,K_1} \right) \qquad (25)$$

and this should be only a small fraction of the valve stroke.

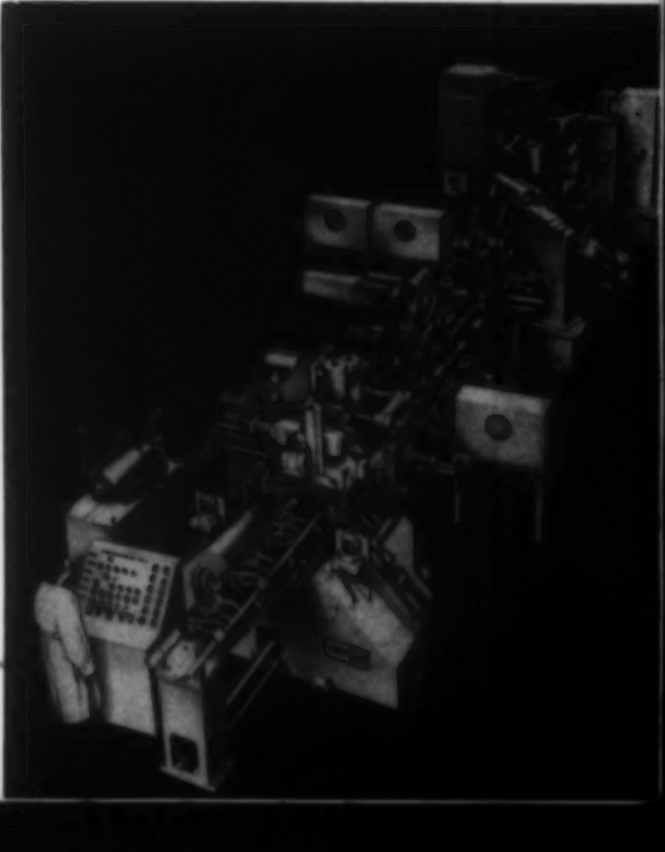
CONTEMPORARY DESIGN

Automatic Machine Doubles As Inspector

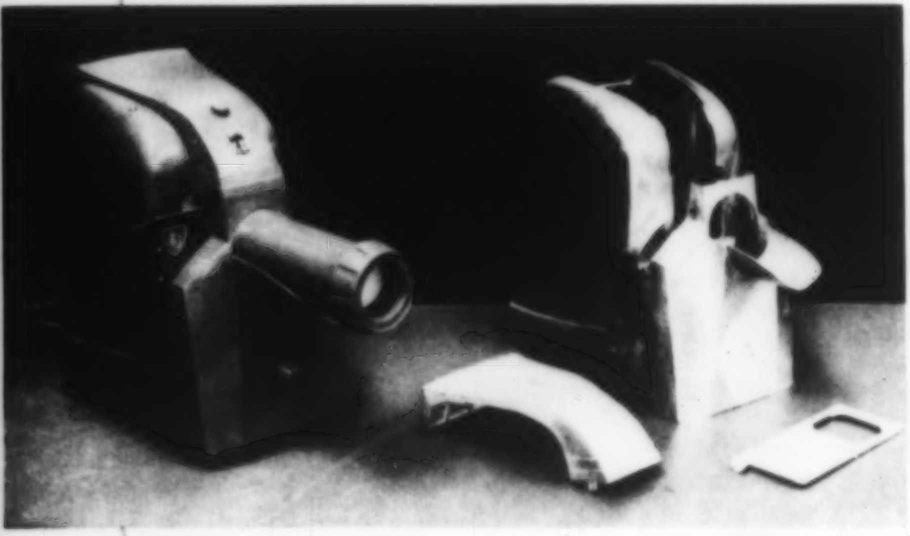
SEVERAL unusual automatic testing features are incorporated in a new 21-station, automatic special machine for processing the intake manifold of a V-8 automotive engine. Most noteworthy of these testing operations is one which automatically tests the manifold passages for leakage and for proper volume of air flow.

Testing for leakage is accomplished by sealing all of the manifold outlets, injecting compressed air, and measuring the pressure drop over a fixed period of time. Openings are sealed by means of steel pads to which neoprene sheets have been vulcanized and which are held tightly against the part by means of hydraulic cylinders during the testing operations. Testing for air volume flow is accomplished by blowing air through the manifold passages in required volume, and any restriction in air passage is then detected through a rise in pressure, indicated on a gage at the inlet. If a part is found to be faulty in these tests, a mechanical memory is activated which causes the part to be rejected and a repaired part moved into the line to replace it at a certain machine station.

Another interesting feature of this machine, made by Snyder Tool & Engineering Co., is an inspection operation which checks to insure that all holes to be tapped are drilled. The machine is so interlocked that, if the hole is not completely drilled or, if drilling has been omitted, the part cannot be indexed into the tapping station. A total of 29 holes is processed as the part moves through the machine and the part is completely machined when it is unloaded. Operations include milling, drilling, core drilling, reaming and tapping. Operation is entirely automatic after loading, except for unloading and reloading when a defective part is reported by the mechanical memory. Production is 130 pieces an hour at 80 per cent efficiency.



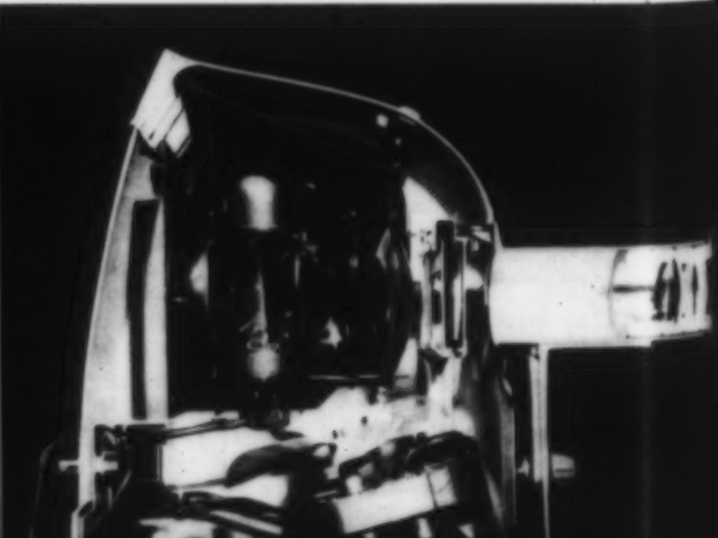
Projector Designed for Easy Assembly



FIVE screws and canopy nut are the only fasteners needed in final assembly of the "Skot" slide projector made by American Optical Co. A large part of this ease of assembly is the result of using three aluminum die castings for the projector housing and slide changer thus eliminating many fasteners which might otherwise be required. Die castings are made by Precision Castings Co. Inc.

Subassemblies in the projector in addition to the slide changer are blower assembly, projection lamp and optical system, lens and lens board. One screw holds both lens barrel and focussing spring in place. A previous design used two rivets and three screws.

Motor-blower unit and optical system are preassembled and installed as units. Two self-tapping screws are used to hold the optical system in place. Holes for these screws are drilled by the supplier of the die-cast housing. One nut holds wiring harness, on-off switch and name plate in place. Two knurled thumb screws hold the motor-blower unit in place. Motor is connected to the main wiring harness by a male plug which is rigidly attached to the blower assembly and automatically makes connection when the unit is installed.



Determining Clearances for

Nonmetallic Journal Bearings

By **Ronald S. Brand** and **Wendell Davis**
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IN RECENT years, the use of nonmetallic materials for journal bearing applications has come into rather widespread use. Because of the low thermal conductivity of these materials, friction heat generated may cause a rather large temperature gradient through the bearing wall. This fact, coupled with the comparatively high coefficient of thermal expansion, may result in a significant change in the clearance between bearing and shaft under operating conditions. This data sheet will enable the designer to predict this change in clearance and the accompanying stresses for a given set of operating conditions. A typical bearing application is depicted in *Fig.* 1.

Basic Design Theory: Equations listed in this discussion are based on the following assumptions:

1. Material behaves elastically, with constant elastic properties (E and ν) throughout.
2. Bearing is confined in rigid metallic housing so that there is no increase in outside bearing diameter and no change in bearing length.
3. Thermal equilibrium has been attained.

The formula relating the decrease in diametral clearance to the other variables of the problem is (symbols are defined in the accompanying *Nomenclature*)

$$\Delta D_i = D_i \alpha_b (T_i - T_o) \left\{ 1 - \left(\frac{D_o^2}{D_i^2} - 1 \right) \times \left[\frac{1 - 2\nu + \dfrac{1 - \nu}{\log_e \dfrac{D_o}{D_i}}}{1 + \dfrac{D_o^2}{D_i^2}(1 - 2\nu)} \right] \right\} \qquad (1)$$

Curves in *Fig.* 2 are plotted from this equation.

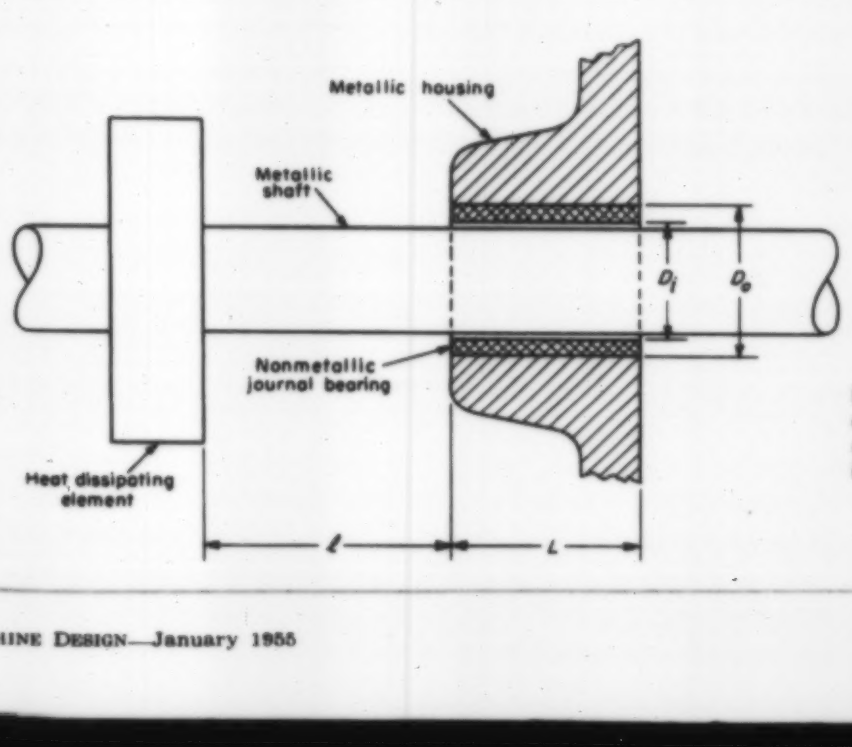


Fig. 1—Cross-section of metallic shaft, nonmetallic journal bearing, and metallic bearing housing

Obviously, the change in clearance is quite sensitive to the value of Poisson's ratio, particularly at the larger D_o/D_i ratios.

The temperature difference, $T_i - T_o$, depends on the amount of heat generated in the bearing and the methods by which this heat is dissipated. The heat generated in the bearing is given by

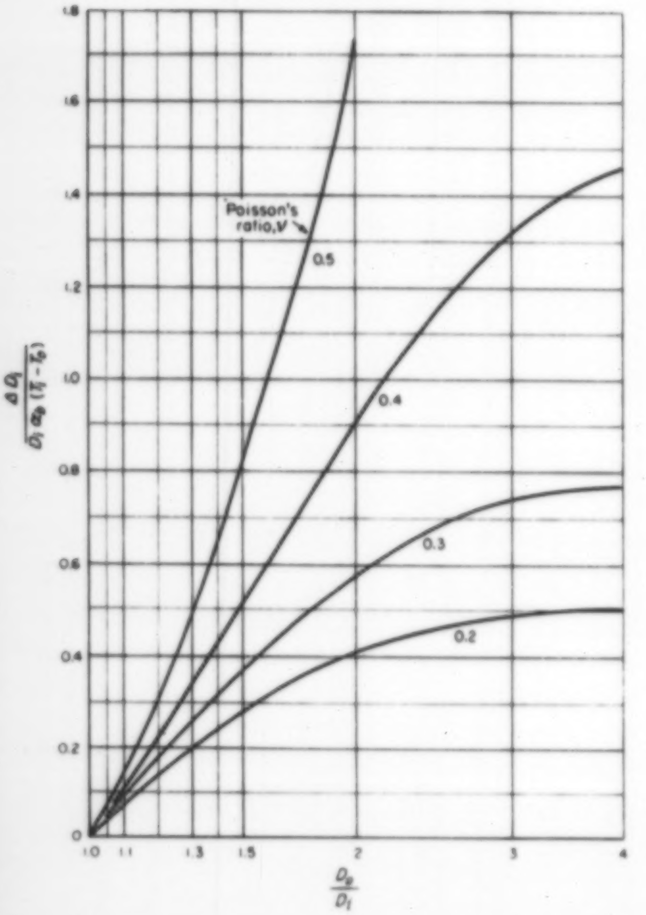
$$Q_f = \frac{60 \pi \mu W D_i N}{12\,(778)} \quad \text{(2)}$$

One of the merits of plastic bearings is that they will run with little or no lubricant. In a force feed bearing a large percentage of the friction heat generated is removed by the flowing lubricant. In a plastic bearing, with little or no lubricant flow, the heat must be transmitted outward through the bearing or conducted along the shaft to some gear, pulley or other member which is capable of dissipating heat. A study of a given design should indicate some point at a distance l from the edge of the bearing where the temperature rise will be slight due to the presence of a heat radiator or reservoir.

Heat conducted along the shaft from the bearing is given by:

$$Q_s = \frac{\pi D_i^2 K_s (T_i - T_o)}{4\,(144)\,(l)} \quad \text{(3)}$$

Fig. 2—Chart for determining nonmetallic bearing clearance



Heat transmitted through the bearing is given by:

$$Q_b = \frac{\pi K_b L (T_i - T_o)}{72 \log_e \dfrac{D_o}{D_i}} \quad \text{(4)}$$

These equations in turn are related by:

$$Q_f = Q_s + Q_b \quad \text{(5)}$$

The temperature rise will also cause an increase in the pressure between the outer bearing surface and the restraining housing. This is in addition to the press-fit pressure which may exist at room temperature. The pressure on the outer surface of the bearing due to thermal effects only is given by

$$p_o = \frac{E \alpha_b (T_i - T_o)}{2\,(1 - 2\nu)} \left\{ \frac{1}{\log_e \dfrac{D_o}{D_i}} \left[1 - \frac{2\,(1 - \nu)}{1 + \dfrac{D_o^2}{D_i^2}(1 - 2\nu)} \right] - \frac{2}{\dfrac{1}{1 - 2\nu} + \dfrac{D_o^2}{D_i^2}} \right\} \quad \text{(6)}$$

Accompanying the external pressure p_o is a tangential compressive stress which is a maximum at the inside surface. This stress may be determined from:

$$\sigma_o = \frac{E \alpha_b (T_i - T_o)}{2} \left\{ \left[\frac{1}{1 - \nu} \right] \times \left[\frac{1 - \dfrac{D_o^2}{D_i^2}(1 - 2\nu)}{1 + \dfrac{D_o^2}{D_i^2}(1 - 2\nu)} - 1 \right] + \left[\frac{1}{(1 - 2\nu)\left(\log_e \dfrac{D_o}{D_i}\right)} \right] \times \left[\frac{1 - \dfrac{D_o^2}{D_i^2}(1 - 2\nu)}{1 + \dfrac{D_o^2}{D_i^2}(1 - 2\nu)} - \frac{\nu}{1 - \nu} \right] \right\} \quad \text{(7)}$$

In applying the preceding method of analysis consideration should always be given to the characteristics of the specific bearing material employed. The effect of temperature on Young's modulus and Poisson's ratio for different plastic compositions is often difficult to evaluate. Available information is frequently meager and not sufficient to permit any definite conclusion to be drawn. While some plastic materials fit the condition of elastic behavior, which was assumed as a basis for the derivation of the equations, others do not, particularly at elevated temperatures. However, from an examination of the chart in *Fig.* 2, it can be seen that the value of Poisson's ratio has a marked effect on the change in clearance whereas Young's modulus does not enter the picture. Thus, to provide an added margin of safety against the possibility of bearing seizure, a value of Poisson's ratio which is slightly greater than the normal accepted value can be selected.

Example Problem: Assume it is desired to determine the proper assembly clearance for a molded nylon* plastic bearing to assure adequate running clearance at the operating temperature. The bearing has the following dimensions and material properties: $D_i = 0.75$-inch, $D_o = 0.90$-inch, $L = 1.25$ inch, $W = 50$ pounds, $N = 3000$ rpm, $E = 400{,}000$ psi, $\nu = 0.4$, $\alpha_b = 55 \times 10^{-6}$ in./in.-deg F, $K_b = 1.7$ Btu-in./hr-ft^2-deg F, and $\mu = 0.1$. Assume this bearing is used around a steel shaft in which $\alpha_s = 6.5 \times 10^{-6}$ in./in.-deg F, $K_s = 300$ Btu-in./hr-ft^2-deg F.

Assume also that the oil flow rate through the bearing is so small that no appreciable heat is carried away by the oil. Friction heat generated must therefore be conducted through the bearing and along the shaft.

If it is assumed that the conductivity of the housing is much greater than that of the bearing, the housing temperature rise is negligible.

In this installation, the heat transmitted along the shaft is dissipated by radiation and convection from a large disk at a distance $l = 1.5$ inches from the edge of the bushing. Heat transfer from the disk is so effective that the temperature of the disk does not rise appreciably. Therefore, the temperature of the shaft at this point, l inches from the edge of the bearing, will be taken to be equal to T_o, the ambient temperature, and the temperature gradient along the shaft to be $(T_i - T_o)/l$.

Friction heat generated is given by Equation 2. Substitution of numerical values yield $Q_f = 228$ Btu per hour.

Heat conducted along the shaft is given by Equation 3. Values may be substituted for all terms except T_i and T_o. This results in $Q_s = 0.613\ (T_i - T_o)$. Similarly Equation 4 gives $Q_b = 0.509\ (T_i - T_o)$. Now from Equation 5, $Q_f = 0.613\ (T_i - T_o) + 0.509\ (T_i - T_o) = 228$ Btu per hour. This results in a value of $T_i - T_o = 201$ F.

For the decrease in bearing bore for $D_o/D_i = 1.2$ and $\nu = 0.4$, it is found from *Fig.* 2 that

$$\frac{\Delta D_i}{D_i\, \alpha_b\, (T_i - T_o)} = 0.225$$

or

$$\frac{\Delta D_i}{D_i} = 0.00247$$

For the increase in diameter of the shaft

$$\frac{\Delta D_i}{D_i} = \alpha_s\, (T_i - T_o) = 0.0013$$

Hence the reduction in diametral clearance per inch of shaft diameter is 0.00247 + 0.0013 = 0.0038, or for the ¾-inch shaft, 0.0028-inch. If it is desired to have a running clearance of 0.002-inch, the clearance at assembly would have to be nearly 0.005-inch.

Nomenclature

D_i = Inside diameter of bearing, in.
ΔD_i = Inside diameter size decrease due to temperature rise, in.
D_o = Outside diameter of bearing, in.
E = Bearing material modulus of elasticity, psi
K_b = Thermal conductivity of bearing material, Btu-in./hr-ft^2-deg F
K_s = Thermal conductivity of shaft material, Btu-in./hr-ft^2-deg F
L = Bearing length, in.
l = Any arbitrary distance from one end of bearing, in.
N = Rotational speed, rpm
p_o = Bearing outer surface pressure due to thermal effects only, psi
Q_b = Total heat conducted through bearing, Btu/hr
Q_f = Friction heat generated, Btu/hr
Q_s = Heat conducted along shaft, Btu/hr
T_i = Inside temperature of bearing, deg F
T_o = Outside temperature of bearing, deg F
W = Radial bearing load, lb
α_b = Coefficient of thermal expansion of bearing, in./in.-deg F
α_s = Coefficient of thermal expansion of shaft, in./in.-deg F
μ = Coefficient of friction of bearing material
ν = Poisson's ratio for bushing material
σ_e = Maximum compressive stress at inner surface of bearing due to thermal effects only, psi

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*du Pont FM 10001.

DESIGN ABSTRACTS

Specifying SURFACE FINISH ... for machined parts

By James F. Hagen and Earl E. Lindberg

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Detroit, Mich.

ALL MACHINED surfaces are composed of thousands of irregularities of various lengths, widths, and heights, with even smaller irregularities on the flanks of the major ones. The surface irregularities of some typical machined surfaces are shown in *Fig.* 1. The magnification of these profiles is approximately 10 times greater in the vertical direction than in the horizontal direction so that the depths of the irregularities are greatly exaggerated in relation to their width.

It has been found adequate for production control to describe the surface roughness by means of a single number related to the average height of the irregularities measured from the mean surface. This number also gives excellent correlation with service performance. Consequently, this method of specifying a surface has been universally adopted.

Roughness Height: Two different parameters may be used to evaluate the average roughness of a surface. They are the AA, arithmetic-average, deviation of the surface from the mean surface and the RMS, root mean square, deviation from the mean surface. These two types of averages are closely related; however, for most machined surfaces the RMS value is approximately 10 per cent greater than the arithmetic average.

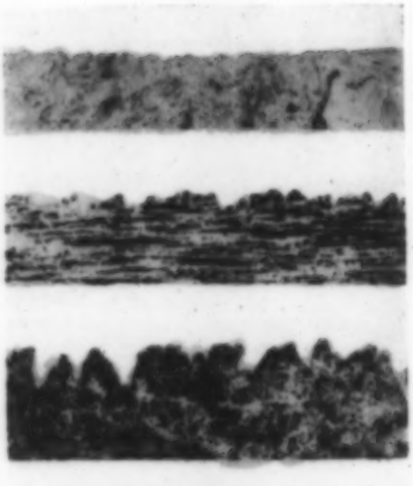


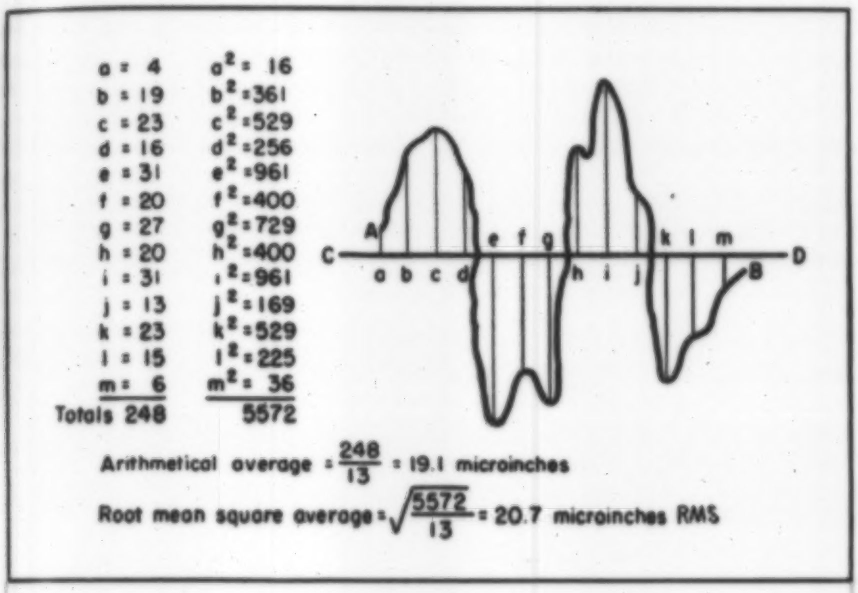
Fig. 1—Microphotographs of profiles of typical machined surfaces. From top to bottom the parts and their average roughness values, in microinches, are: connecting - rod bushing, 8; valve stem, 24; cylinder bore, 60; and brake drum, 110. In these photographs, vertical magnification is ten times greater than horizontal

The RMS value has been widely used in the past. At the present time, however, the arithmetic average is preferred and is specified as the standard rating for surface roughness in practically all of the standards on surface finish.

The meanings of these terms, arithmetic average and RMS, are illustrated in *Fig.* 2. The curve *AB* represents a typical surface profile and the straight line *CD* represents the mean surface. The mean surface is indicated by a straight line located on the profile in such a way that the algebraic sum of the areas included between the mean surface and the true surface is zero; areas above the mean surface are considered positive and those below negative.

The RMS value may be calculated from the profile by measuring the vertical distances from the mean line to the profile at a number of equally spaced intervals along the mean line, squaring the measurements, summing the squares, dividing by the number of measurements, and taking the square root of this quotient.

Arithmetic average may be obtained by measuring the vertical distances from the mean line to the profile at a number of equally spaced points, summing these measurements, and dividing by the



$a = 4$ $a^2 = 16$
$b = 19$ $b^2 = 361$
$c = 23$ $c^2 = 529$
$d = 16$ $d^2 = 256$
$e = 31$ $e^2 = 961$
$f = 20$ $f^2 = 400$
$g = 27$ $g^2 = 729$
$h = 20$ $h^2 = 400$
$i = 31$ $i^2 = 961$
$j = 13$ $j^2 = 169$
$k = 23$ $k^2 = 529$
$l = 15$ $l^2 = 225$
$m = 6$ $m^2 = 36$
Totals 248 5572

Arithmetical average $= \frac{248}{13} = 19.1$ microinches

Root mean square average $= \sqrt{\frac{5572}{13}} = 20.7$ microinches RMS

Fig. 2 — Relationship of arithmetic-average and root-mean-square values for determining surface roughness. RMS value is approximately 10 per cent greater than the arithmetic average

number of measurements. The arithmetic average is ¼ to 1/5 the total peak-to-valley height for machined surfaces. For the finer finishes, however, this ratio may be as small as 1/10.

One of the reasons that the arithmetic average is preferred is that it is understood more readily. In addition, RMS value cannot be readily measured. The instruments which are professed to read RMS values actually measure something nearly proportional to arithmetic average. A third reason for preferring the arithmetic average is that eventual international standardization is brought closer because the British now use the arithmetic average.

Fortunately, switching from the RMS system to the arithmetic-average system does not necessitate changing the roughness values which are specified in RMS units on existing drawings. As mentioned previously, the arithmetic-average roughness value for most machined surfaces is about 10 per cent less than the RMS value. Thus, the numerical difference between the roughness values in the two systems is small enough, and in the right direction, so that all surfaces which are smooth enough to pass an RMS inspection will also pass an arithmetic-average inspection.

Roughness-Width Cutoff: Conditions of roughness, waviness, and roughness superimposed on waviness in are illustrated in *Fig.* 3. The closely spaced irregularities of short wave lengths constitute roughness, while the widely spaced irregularities of longer wave lengths constitute waviness. For this idealized surface it is easy to differentiate between the two. For actual machined surfaces, however, it is often difficult to distinguish between roughness and waviness because there are irregularities of all wave lengths present and the short wave lengths flow smoothly into the long wave lengths. The roughness-width cutoff, therefore, may be used to differentiate between the two.

The roughness-width cutoff is the maximum width in inches of surface irregularities to be included in the measurement of average roughness. The cutoff determines the distance over which the surface irregularities are to be averaged to obtain the roughness value. Irregularities having spacing greater than the roughness-width cutoff are called waviness and are not included in the measurement of roughness.

In *Fig.* 4 is shown the true profile of a machined surface and its interpretation by an instrument with roughness-width-cutoff settings of 0.030, 0.010 and 0.003-inch. Each profile shows only those irregularities that are sufficiently close together to be measured as roughness for the particular roughness-width cutoff. The very short irregularities occur in all the profiles. The measuring instrument, however, is less sensitive to irregularities having a wave length greater than the roughness-width cutoff. For each profile all irregularities have been attenuated that have a wave length longer than the cutoff. The profile for the 0.030-inch cutoff is little different from the true profile because in the surface there are no irregularities with a wave length longer than 0.030-inch. In the profile for the 0.010-inch cutoff, the coarser irregularities—those with a wave length longer than 0.010-inch — have been reduced in amplitude and the finer irregularities are relatively unchanged. The profile for the 0.003-inch cutoff includes only the irregularities with a wave length less than 0.003-inch.

For this particular surface profile, the effect of reducing the roughness-width cutoff, and thereby excluding some of the irregularities, has been to decrease the average roughness value, which is indicated by the values given. On the other hand, if all of the surface irregularities were as fine as those of the bottom profile, the roughness value would be the same for all three roughness-width cutoff settings.

For certain applications, adequate control of surface rough-

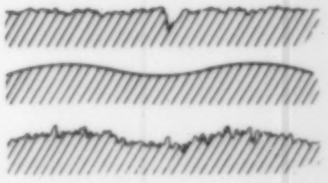


Fig. 3—Trace of an actual surface profile illustrating roughness (top), exaggerated waviness (center) and roughness superimposed on waviness (bottom)

ness may require the use of a particular roughness-width cutoff. For example, a large cutoff value is used where the contact area between two mating surfaces is important. Conversely, in cases where parts may be subject to fatigue failure, only the surface scratches which serve as stress raisers are important and a small cutoff gives a more significant value. In selecting a roughness-width cutoff, care must be taken to choose one that measures important irregularities.

The standard roughness-width cutoff values are 0.003, 0.010, 0.030, 0.100, 0.300, and 1.000 inch. Experience has shown that the 0.030-inch value is preferred for most applications, and this value is used unless there is a definite reason for specifying a different one.

Surface-Finish Symbols: Surface finish is usually specified on drawings by means of symbols for surface roughness, waviness, and lay. Generally these symbols replace notes or symbols calling for a specific machining method.

A surface can be more accurately described and duplicated by the proper use of surface symbols than by specifying the manufacturing process, an operation which may be subjected to many different interpretations. Usually, the designer specifies surface finish, and unless experience indicates that only one processing method will give adequate performance, the decision on the method of machining is left to the manufacturing group which has full knowledge as to which means of producing the parts will best fit its equipment.

The symbol specified by the latest proposed revision to the *American Standard, Surface Roughness, Waviness and Lay* (*ASA* B46.1), for designating surface finish is the check mark and extension, *Fig*. 5*a*. This mark is put on the drawing wherever control of surface finish is required. The point of the symbol may be on a line indicating the surface, on a witness line, or on a leader line pointing to the surface. The short leg may be wider if desired. The proportions for the surface-finish symbol are given in *Fig*. 5*b*.

The methods of designating roughness, waviness, roughness-width cutoff, and lay in conjunction with the surface-finish symbol are depicted in *Fig*. 6. Only those ratings that are necessary to specify the required surface should be shown on the symbol.

The average roughness value is placed adjacent to the left side of the long leg, *Fig*. 6*a*. The use of one number indicates the maximum permissible roughness value; any lesser value is acceptable. When two numbers are used, *Fig*. 6*b*, they indicate the permissible maximum and minimum values of roughness.

The waviness-height rating, when required, is placed above the horizontal extension line, *Fig*. 6*c*. This rating represents the maximum peak-to-valley height of waves in inches; any lesser value is acceptable.

Where required, the waviness-width rating (not shown in *Fig*. 6) is placed immediately to the right of the waviness-height rating. This number represents the maximum value in inches and any lesser value is acceptable. A percentage contact-area value may be used as an alternate to waviness-width rating.

The roughness-width-cutoff value is placed to the right of the long leg and directly below the horizontal extension line, *Fig*. 6*d*. The value of the roughness-width cutoff is not designated unless a value other than the standard 0.030-inch is required.

Lay designation is indicated by the lay symbol placed to the right of the long leg, *Fig*. 6*d*. The symbol is used only if considered essential. The standard symbols for designating lay are shown in *Fig*. 7.

Design Considerations: A comprehensive program of surface-finish control must clearly state which surfaces are critical. Where no surface finish is indicated, any machining operation that gives the required dimensional accuracy also gives an adequate surface finish. On many surfaces, finish control is not required because service life is not affected by surface characteristics. It is important that these

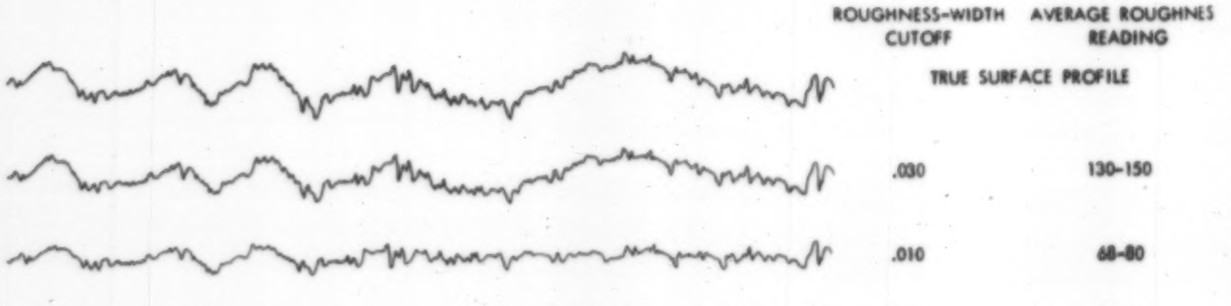


Fig. 4—True surface profile and profile as determined by three separate roughness-width-cutoff figures, in inches. Decreasing the cutoff figure results only in eliminating indications of long wave-length irregularities, which then fall under the waviness classification

surfaces receive no surface-finish designations on drawings; otherwise, the cost of the product may be unnecessarily increased and also the truly important surface-finish marks may receive less attention.

Proper control of surface finish can eliminate many rejects and failures and, consequently, can result in better products at lower costs. Care must be taken to avoid over-specification, however, because normally the cost of producing a surface becomes progressively greater as the permissible roughness and waviness become less. Generally, other considerations being accounted for, the ideal finish is the roughest one which will do the job.

The designer, of course, has the responsibility in each case of selecting the surface finish that will give maximum performance and service life at the lowest possible cost. Decisions should be based on past experience with similar parts, on engineering tests, or on field-service data. Judicious selection will be influenced by such factors as size and function of the part, type of loading, existence of load reversals, speed and direction of movement, physical characteristics of materials in contact, type and amount of lubrication, contaminants and temperature. Because of the many factors which are involved, it is often difficult to foretell accurately the proper surface finish.

The two most important reasons for surface-finish control are to reduce friction and to regulate wear. Wherever a film of lubricant must be maintained between two moving parts, the height of the surface irregularities must be less than the thickness of the oil film, even under the most severe operating conditions. Bearings, journals, cylinder bores, piston pins, bushings, pad bearings, helical and worm gears, seal surfaces and machine ways are examples for which this condition must be fulfilled.

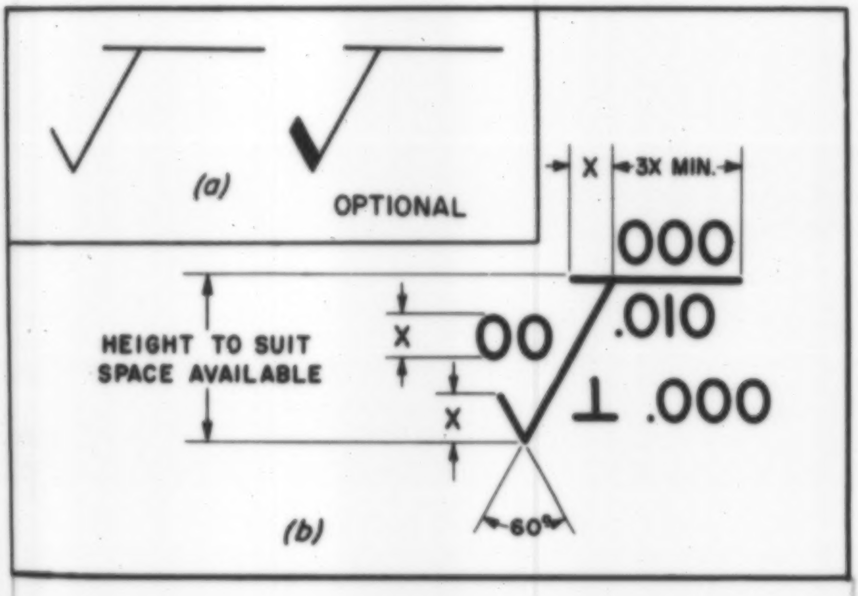


Fig. 5—Proposed standard surface symbol, *a,* which may be drawn with its point on a line indicating the surface, on a witness line, or on a leader line pointing to the surface. Widening the short line is optional. Symbol proportions are indicated at *b;* zero is omitted before the decimal point for maximum space utilization

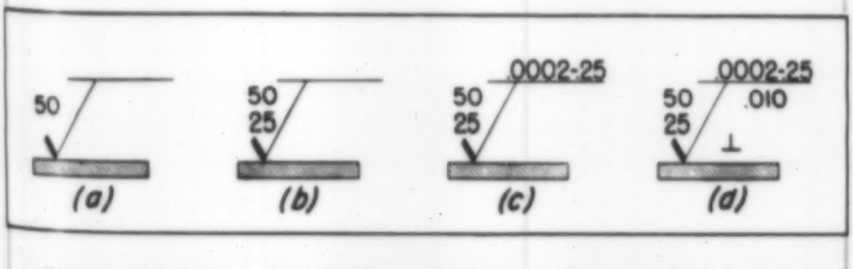


Fig. 6—Typical surface-finish symbolism: *a,* One number denotes average roughness and *b,* two numbers show permissible maximum and minimum roughness values. Waviness-height rating can be added as at *c,* as can the lay symbol and roughness-width-cutoff value, *d*

Surface finish is important also to the wear service of certain pieces which are subjected to dry friction, such as: machine tool bits, threading dies, stamping dies, rolls, clutch plates and brake drums. Smooth finishes are essential on certain high-precision pieces. In injectors, high-pressure cylinders, and similar mechanisms, smoothness and lack of waviness are essential in order to meet dimensional tolerances and to permit proper operation at high pressures.

Surface finish often must be controlled for the purpose of increasing the fatigue strength of highly stressed members which are subjected to load reversals. A smooth surface eliminates the sharp irregularities which are the greatest potential sources of fatigue cracks.

Smoothness is often essential for eye appeal of the finished product. Surface finish is controlled for this purpose on such articles as rolls, extrusion dies, and precision casting dies. Finish control also may be essential to insure quiet operation of gears and similar parts.

In general, with compatible surfaces and complete lubrication, the smoother the surface, the better the results. However, the goal of working toward perfectly smooth surfaces is often not economical, nor is it a guarantee that the finished part will perform to the best advantage. In some applications, surfaces with a specific roughness perform better than either smoother or rougher surfaces.

For example, a specific roughness is required in order to achieve wear-in of cylinders in internal-combustion engines. As a result of imperfect geometry, running clearances, and thermal distortions, these surfaces must wear in by actual removal of metal. The surface finish must be a compromise between sufficient roughness to give proper wear-in and sufficient smoothness to give the expected service life. Too smooth a surface will produce too slow an initial wear. In fact, the surfaces may never wear in and improper clearances may result in local hot spots and high oil consumption.

From an article entitled "Design Considerations Applying to Specification of Surface Finish for Machined Parts" which appeared in General Motors Engineering Journal *for July-August*, 1954.

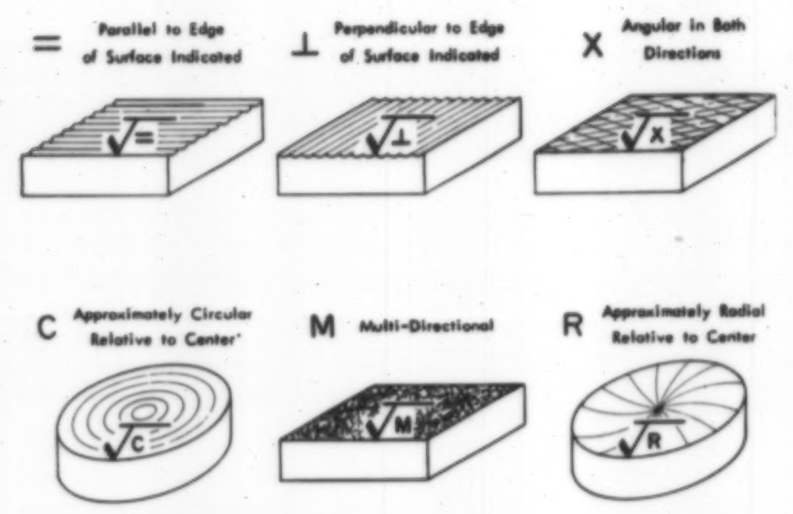

=
Parallel to Edge of Surface Indicated
⊥
Perpendicular to Edge of Surface Indicated
X
Angular in Both Directions
C
Approximately Circular Relative to Center
M
Multi-Directional
R
Approximately Radial Relative to Center

Fig. 7—Standard symbols for designating lay of surface irregularities, which may be parallel or perpendicular to the edge, angular in both directions, approximately circular, multi-directional or approximately radial

Design Considerations for

Shell Molding

By S. B. Donner
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Hillside, N. J.

IN CONTEMPLATING shell molding as a possible manufacturing technique, the designer is no doubt concerned with the quality which the method affords and the economies he may derive in machining and finishing operations.

Basic tenets of good steel casting design apply to shell molding in equal degree as for sand molding, despite early claims that once credited the technique with certain properties which would permit metal solidification rates to be controlled. As in sand molding practice, abrupt changes in section, sharp corners and heavy "T" sections must be avoided, minimized, or streamlined to negate shrinkage and tearing. The principles of controlled directional metal solidification should be used in exactly the same manner as for sand. Application of those principles is especially critical for shell castings, since the method possesses some very real limitations, as well as advantages, not common to sand practice. For example, except for a limited use, internal or external chills cannot be utilized to equalize solidification rates in unequal metal sections, due to the mechanical nature of the mold-forming operation. Similarly, risers and feed-heads cannot always be located with the freedom and choice common in sand molds.

Other limitations which require a certain amount of attention from design personnel are: (1) The ordinary inability to use loose pattern pieces to form backdrafted portions of a mold, although under certain circumstances and at relatively high cost backdrafts may be successfully cast by means of mechanically retractable elements in the pattern equipment, and (2) "cheeks" cannot be made, an important factor which also limits the casting of backdrafted items and the usage of feed heads in center locations.

There are some inherent technical advantages which are made use of in shell molding. For one thing, there are no stress tearing problems due to resistance of mold or core sections. The thin shell section burns out and crumbles in a matter of several seconds after casting, and offers no resistance to solid contraction. It is possible to use intricate coring, both in this shell and conventional core mixes, to produce accurately located cavities. Due to the low mold frictional coefficient, extremely thin metal sections, often as small as 1/10-inch, are run.

Casting Tolerances: If a broad rule for blanket tolerances must be applied, most shell-molded stainless or high alloy castings of average squeeze machine size, say approximately 2 to 3 pounds can be held ±0.010-inch on most dimensions.

Casting Weights: So far as we know, no firm weight limitation

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has been placed on shell castings which can be made. We are extremely optimistic about founding very substantial castings in shells. Although our heaviest casting runs approximately 135 pounds at present, we have heard of castings in gray and nodular cast iron which ran to 800 pounds.

Surface Finishes: The excellence of the surface finishes which are obtainable in stainless and high-alloy steel shell castings is one of the more attractive aspects of shell molding. The designer is cautioned, however, against accepting uneducated or over-optimistic claims for uniform casting surfaces equivalent to wax investment casting products. While long-run items with a fairly consistent RMS value not exceeding 125 have been produced, blanket claims for finishes of that order can not be made for the high-alloy steels. Among the many variables which affect finish profoundly are alloy type, chemistry balance of the alloy, sand and resin type and fineness, pouring temperature and gating practice. As a general rule, tool type alloy and high-carbon steels will yield very fine finishes with properly engineered molds and correct pouring temperatures, to the point where sand or shot-blast cleaning will actually impair finishes. The straight chromium steels are not quite as good, and the austenitic stainless types are somewhat inferior to both of the former.

The largest cost items in the shell mold process are the pattern plates, which may run from $400 to $10,000 or more and are the heart of the process. Intricate pattern design is not necessarily more costly, but intricate pattern partings which may be required by off-center or staggered pads, or other irregularities, will raise pattern and per pound costs very appreciably. Special pattern equipment with retractable elements for producing back-drafted sections is very expensive as well. High finish requirements may require the use of expensive additions to the molding mixture, precise molding and casting techniques and custom cleaning room treatment, all of which are reflected in increased casting cost figures.

Sufficient volume is the major prerequisite for economical shell-mold castings. The necessary volume will vary depending upon the casting. Although runs of 500 pieces or less are often justified by reason of large savings in machining, as a rule the volume should run into the thousands if pattern costs are to be satisfactorily amortized.

From a talk entitled "Shell Molding—Design Considerations" given at the Design Engineers Conference held at the Cooper Alloy Foundry Co., Hillside, N. J. in June, 1954

Selecting and Applying

Wire Strain Gages

By John Tarbox
Application Engineer
Consolidated Engineering Corp.
Pasadena, Calif.

RESISTIVE wire strain gages can be adapted to make measurements of high accuracy under a variety of conditions. They can be made to operate at furnace temperature or freezing cold, in desert air or under water.

The usual form of strain gage consists of a short length of small (approximately 0.001-inch) diameter wire of high electrical resistance. To keep the gage length short, the wire is formed into a grid. Wire mounting and protection, are simplified by cementing the wire between two thin pieces of paper. In application, the gage is cemented to the member to be tested. Flat or curved shapes are easily accommodated; no expensive preparation is required, no "gage lines" need be scribed. A typical strain gage is illustrated in *Fig.* 1.

When the test member is strained, so is the bonded gage. As the wire is strained its electrical resistance changes. This resistance change is directly proportional to the strain in the wire, and the strain in the wire is directly proportional to the strain in the member.

Selection of the best type of gage for a specific application requires consideration of the constituents of the gage likely to be affected by test conditions. The following discussion treats some of the important factors involved.

Area of Measurement: In use, each infinitesimal portion of the strain gage is intimately bonded to the member being tested and follows its movements in both tension and compression. It measures the average of strains along the whole gage length. If strain in a localized area is needed, a short gage length should be chosen.

Stress Amplitude: "Gage factor" and the expected amplitude of the stress, and consequent strain, determine the gage output at maximum excitation power. Amplitude (and frequency) of the output will determine whether sensitive galvanometers may be used directly, or whether amplification is required. Gages with high gage factors may be obtained, but the range of ready availability for such gages is limited.

Complexity of Stress: Single-grid strain gages are designed to measure only those strains parallel to the strain axis. Transverse-axis sensitivity is generally less than 2 per cent of the major-axis sensitivity. When strain directions are unknown, it is necessary to use a multiple array of gages disposed

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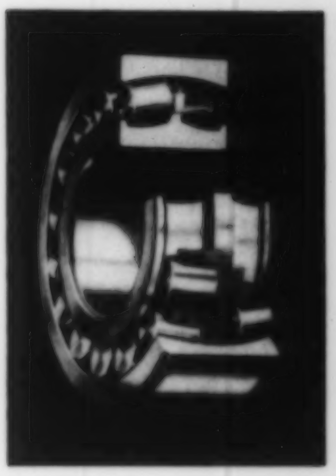
are designed with integral center flange on inner race to provide positive radial stability and positioning for thrust loads



This center flange guides the rollers accurately and friction is reduced to a minimum.

Other performance-building features include accurate geometrical conformity between races and rollers to provide ultimate load carrying capacity; carefully heat-treated races and rollers for maximum resistance to shock and wear; one-piece machined bronze cage for each path of rollers to allow thorough lubrication and give freedom of operation.

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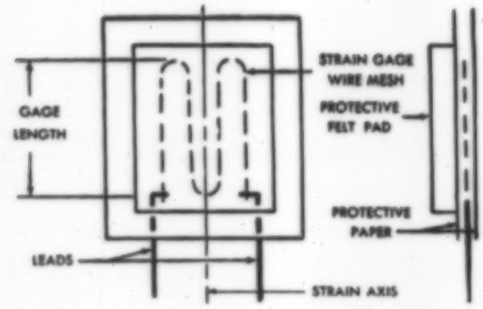


Fig. 1—Top and side views of a typical resistive wire strain gage

to permit later calculations of the magnitude and direction of the principal strains. To aid in this type of measurement, special multiple arrays called "Rosette" gages have been developed. Some of these are sketched in *Fig.* 2.

Strain Frequency: In general, two classes of strain work are encountered. The first is long-term examination of static or slowly varying forces, requiring a gage which gives consistent output under varying environmental conditions. While all strain-gage wire is specially selected and drawn to maintain uniform diameter, ductility, temperature coefficient, and resistance, static or "quasi-static" work requires a special wire with an extremely low temperature coefficient. Such a wire has been developed under the trade name, "Constantan." It is a copper-nickel alloy and has a gage factor of approximately 2.0.

The other class of work deals with high frequencies, often at low amplitudes. This work requires fatigue resistant wire and gages of high output, even at the sacrifice of long-term "stability." For this, "Iso-elastic" wire was developed. It is a complex alloy of iron, nickel, chromium, manganese, silicon, molybdenum, carbon and vanadium. It has a gage factor of approximately 3.5. When fatigue studies are made, the strain-gage leads must also be specially manufactured. For fatigue work, "dual-lead" gages are available with long-flex-life, low-hysteresis leads.

Thermal Conductivity: High heat conductivity of the test member may permit the gage to be operated at higher energizing power levels without danger of electrical overheating. On massive steel and aluminum members, power levels of one watt are often used. On plastics and small metal members, lower levels, in the order of one-fourth watt, should be maintained.

Ductility: Care must be taken not to strain the gage wires beyond their limit of proportionality. In general, they may be strained to 1 per cent elongation (10,000 micro-inches/inch) without damage. Some are restricted to 0.7 per cent elongation. "Post Yield" gages are available for higher strains.

Shape: The resistance-wire strain gage can readily be fastened to a curved surface, such as a pipe. With gage lengths as short as 1/32-inch available, even small-diameter tubing can be accommodated. Standard gages are protected with sturdy, rag bond paper. Where other considerations are not restrictive, the use of thin protective papers simplifies fastening to curved surfaces and shortens the cement drying time by permitting faster evaporation.

High Temperature: Standard paper-base gages with nitrocellulose cement are serviceable to 180 F. For higher temperatures, gages with the wires sandwiched between two paper-base Bakelite wafers are provided. These will give continuous operation to 300 F, with limited service to 500 F. These gages must, of course, be fastened with Bakelite-type cement.

Low Temperature: At temperatures below −20 to −30 F the cellulose acetate cements will tend to

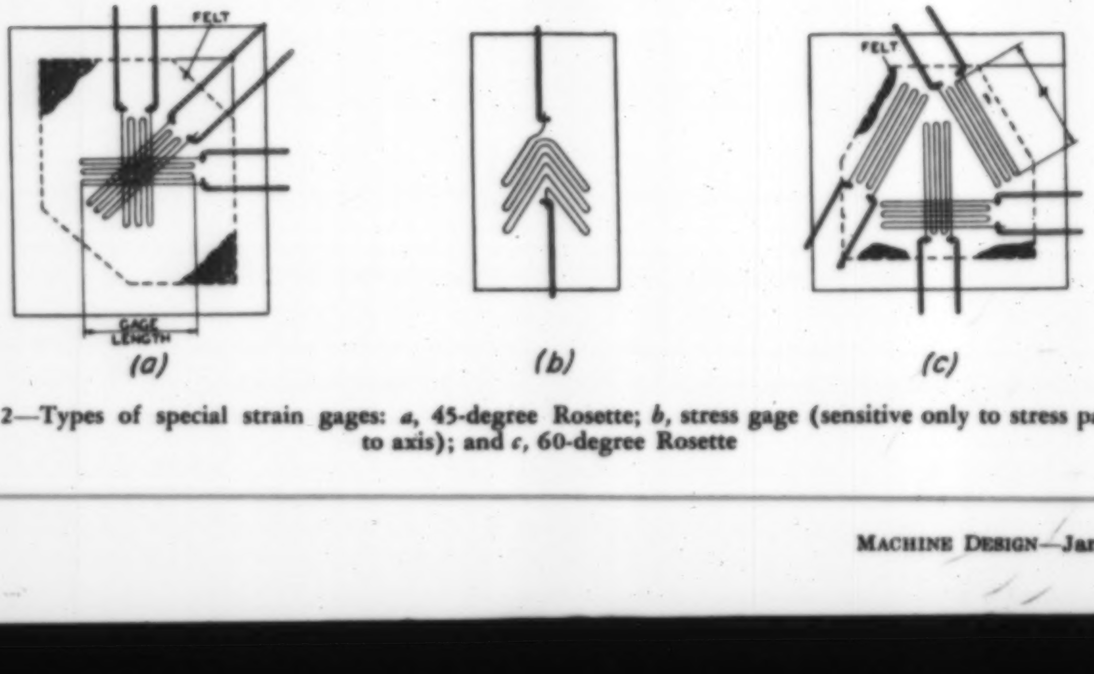
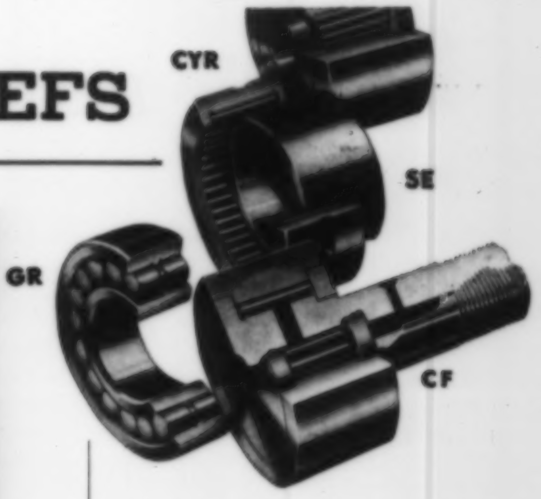
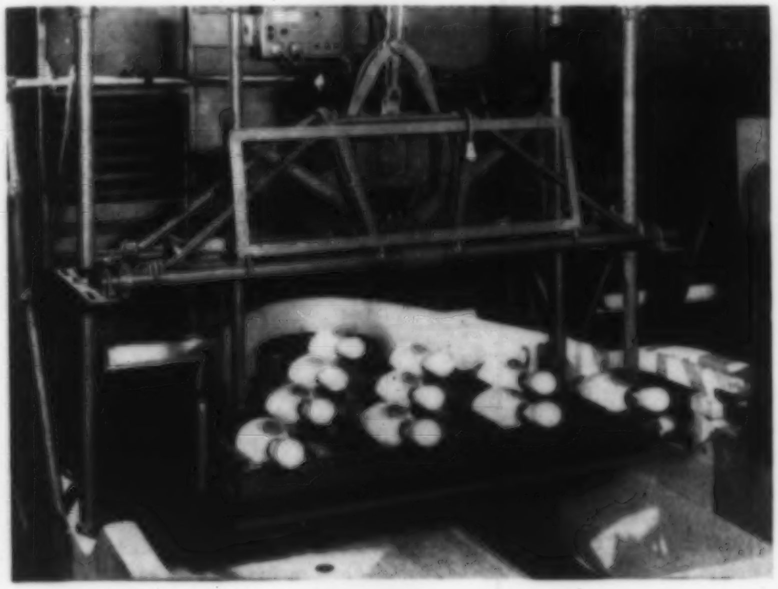


Fig. 2—Types of special strain gages: *a*, 45-degree Rosette; *b*, stress gage (sensitive only to stress parallel to axis); and *c*, 60-degree Rosette

McGILL BEARING BRIEFS





CAMROL CF bearings ADD TO SAFETY of 22,000 Brunswick-Balke-Collender semi-automatic pinsetters now in use

When the pinboys "set 'em up in the other alley" a McGill CAMROL Cam Follower helps them do the job without danger to themselves or damage to the pin-setting machine.

Known as the B-10 Semi-Automatic Pinsetter, this machine is a product of The Brunswick-Balke-Collender Company and is in use on 22,000 individual bowling lanes throughout the world.

In these machines the CAMROL CF bearing is used in the safety latch mechanism to lock the cam action and prevent the machine from recycling during pin setting. Used by the company for 4 years, the CAMROL bearing has given no trouble despite the literally millions of cycles these 22,000 machines have been operated.

CAMROL Cam Follower bearings utilize a full complement of small diameter followers with outer race and integral stud and flange custom heat treated for the ultimate in radial and shock load capacity.

Precision tolerances on all grinding surfaces with simplified lubrication minimizes internal wear and increases bearing life. Both starting and running friction are reduced to a minimum.

McGill designed and built the first Cam Follower and used 20 years of experience with thousands of applications to perfect the right Cam Follower for any cam action application.

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A revised 140 page Bearing Selection Guide, complete with 30 pages of vital engineering data, has been released by the McGill Manufacturing Co. Ask for Catalog No. 52.

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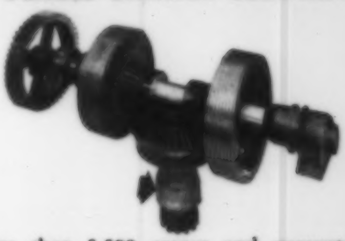

More than 5,500 cranes and excavators built by Schield Bantam since 1945 use CAMROL CF Bearings in SHIFTING COLLAR vertical swing shafts and drum clutch applications. With maintenance negligible and performance excellent the manufacturer asserts, "Using CAMROL CF Bearings offers an overall price advantage and insures maximum product quality."

PINES PRESSURE DIE HOLDER PUTS up to 18,000 POUND LOAD on CAMROL CYR BEARING

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embrittle and impair the bond between member and gage. Bakelite gages and cements, serviceable at high temperatures, will also perform at temperatures as low as −60 F. Moisture is an ever-present hazard at low temperatures, and to prevent excessive electrical "leakage", waterproofing of the gage and exposed leads is necessary.

Temperature Changes: Changes in temperature will cause changes in the resistance of the strain-gage wire. To the measuring instrument, this resistance change appears exactly like a strain. Several methods can be used to lessen or cancel this effect. Wire with a low temperature coefficient, such as Constantan or Advance is one preventive. Special temperature-compensated gages, which practically cancel out temperature effects, are made to suit steel or aluminum structural members. Most commonly used, however, are techniques which permit cancellation of temperature effects in the measuring instrument circuits.

Humidity: Although normal cementing techniques give adequate protection for most usage, high humidity demands special waterproofing treatment. Grease or wax coatings give good service for general humid conditions. For the utmost stability, the use of Bakelite gages and cements is recommended by the manufacturer. With such gages and leads waterproofed with neoprene, months of service, even under water, can be achieved.

From "Strain Gages—Operation, Techniques, and Theory" in CEC Recordings, *September-October*, 1954.

Design for Turbocharging

. . . improves gas engine performance

By Carlton A. Chamberlain and George H. Bollman
Clark Brothers Co.
Olean, N. Y.

FUEL consumption of present high-compression two-stroke gas engines can best be lowered by reducing scavenging load on the crankshaft. If this load is removed from the crankshaft, energy must be supplied from some other source in the engine. Exhaust gas contains the largest amount of heat rejected from the engine (as much as 40 per cent of the heat input) and is at a relatively high temperature level. It is, therefore, the best potential source of energy for this purpose. But, regardless of its temperature, it is not a useful medium unless its pressure is elevated above atmospheric.

A turbine placed in the exhaust line of the engine raises the back pressure on the exhaust in the same way that a fixed orifice would. By expanding the hot exhaust gases to atmospheric pressure, the turbine recovers energy which is absorbed by a scavenging blower on the same shaft, *Fig.* 1.

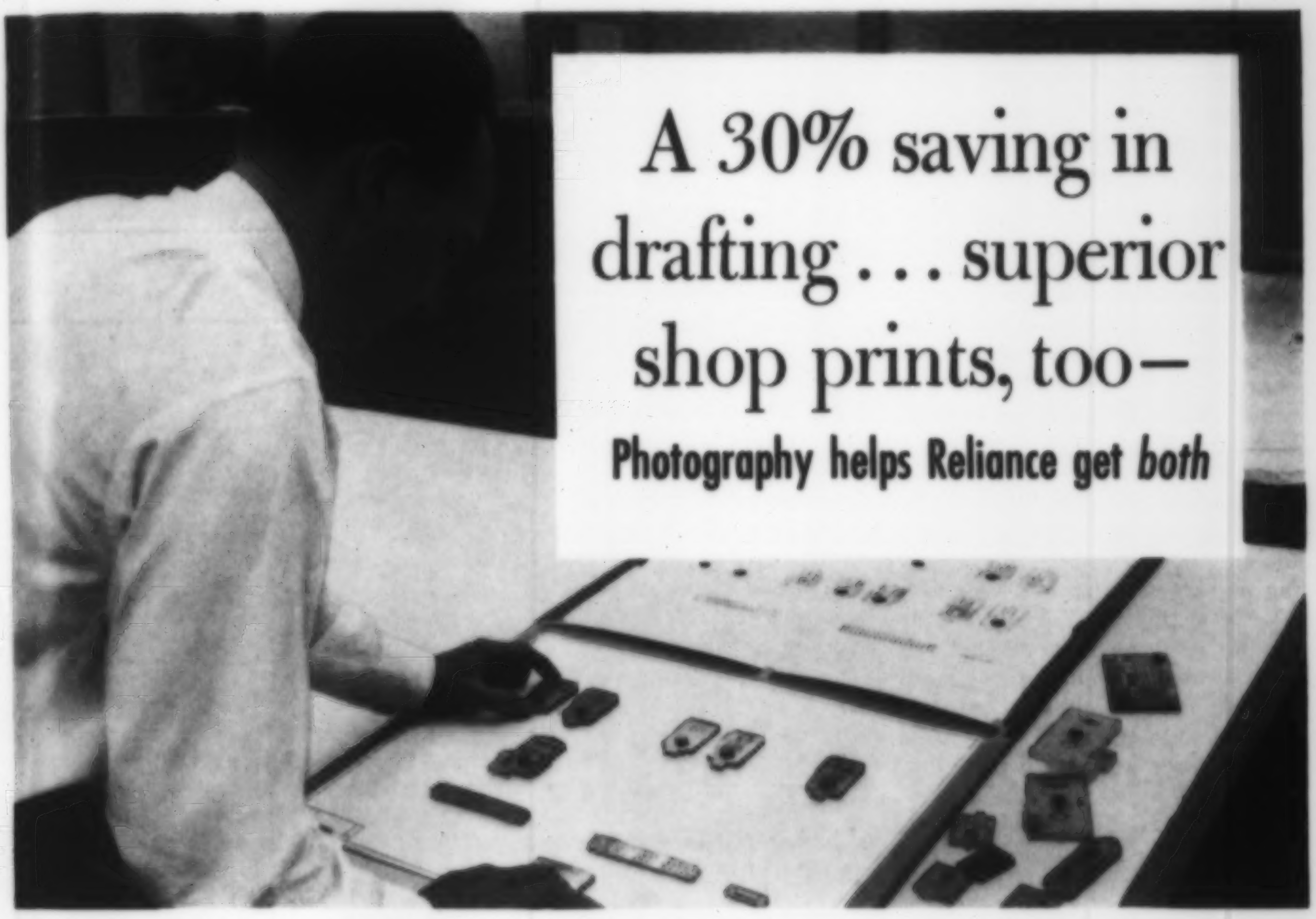
The higher the engine load, the higher the scavenging power requirement, but also the greater the exhaust energy available for this duty. With a load increase, exhaust-gas energy is increased in the form of a rise in temperature. The turbine accelerates to a higher speed, and by driving the blower along with it, produces an increase in inlet airflow which in turn modifies the rise in exhaust temperature. With the increase in air and exhaust flow a rise in supercharging pressure level occurs due to the restriction to flow imposed by the turbine. Air flow, and inlet and exhaust pressures are automatically readjusted for each increment of engine load, both up and down. The turbocharger, then, varies the air flow and charge density in relation to engine load, accomplished without impairing mechanical efficiency of the engine.

If the turbocharger is matched properly to the engine, and its component efficiencies are high enough, thermal loading of the engine is even less than for a conventional, nonturbocharged high-compression engine. Thermal loading is held down in spite of the increased mean effective pressures by virtue of the increased cooling effect of more and denser scavenging air, and because a somewhat leaner mixture can be employed. This lower thermal loading of the engine is evidenced by the sharply reduced jacket water-cooling duty.

The amount of supercharging becomes limited in the two-cycle gas engine by temperature of the scavenging air. As the pressure level is raised, so is the blower-discharge temperature; at some point the compression temperature for the power cylinder will become so high that detonation cannot be avoided. At this point, load range of the engine can be extended by cooling the scavenging air after compression in the blower. Such cooling forestalls the detonation point by lowering the compression temperature and by providing better cylinder-wall cooling.

Function of Mechanical Overdrive: Typically, in any arrangement of a constant-pressure turbine driving a compressor which in turn supplies air to be expanded in the turbine after being heated (in the combustion chamber in the case of an internal-combustion gas turbine, and in the engine in this case), the unit will not be self-sustaining below certain speeds regardless of the turbine-inlet temperature. Additional energy must be supplied in some form or another to prevent the turbocharger from decelerating below this critical point in speed.

Actually, a considerable margin should be allowed above this speed



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because turbocharger acceleration as the turbine-inlet temperature is increased is very low in the region just above this critical speed. Without this margin, it would not be practical to apply a large increment of load to the engine suddenly as the fuel mixture would become excessively rich until the turbocharger speed came up, and this could result in detonation or even stalling of the engine.

In order to accelerate the turbocharger to a point above this critical speed at the time of starting the engine, and to maintain it during periods of idling and very low-load operation, a mechanical drive linking the engine crankshaft to the turbocharger shaft through an over-running clutch has been incorporated in one case. This drive also includes a hydraulic coupling to isolate the engine torsional vibrations from the high-speed portion of the drive. The clutch involves no frictional components, its action being accomplished by draining the hydraulic coupling when the drive is not required. Only a small fraction of the ultimate blower horsepower must be transmitted, and it is completely disengaged during the vast majority of the operating time of the engine.

New Turbocharged Engine Design: In spite of the comparatively small increase in the mechanical stresses on the engine, the indicated horsepower having been increased only 16 per cent to gain a 33 per cent increase in brake horsepower, completely new engines have been designed for the turbocharged type of operation. Basic change in the design is the adoption of the enbloc type of construction with removable power cylinder liners in place of individual cylinders which characterized previous engines, *Fig.* 2. This has provided not only greater structural strength and rigidity but has made possible other features which contribute to improved performance of the engine.

***From a paper entitled "Turbocharging Two-Stroke Gas Engines" presented at the ASME Oil & Gas Power Conference in Kansas City, Mo., June,* 1954.**

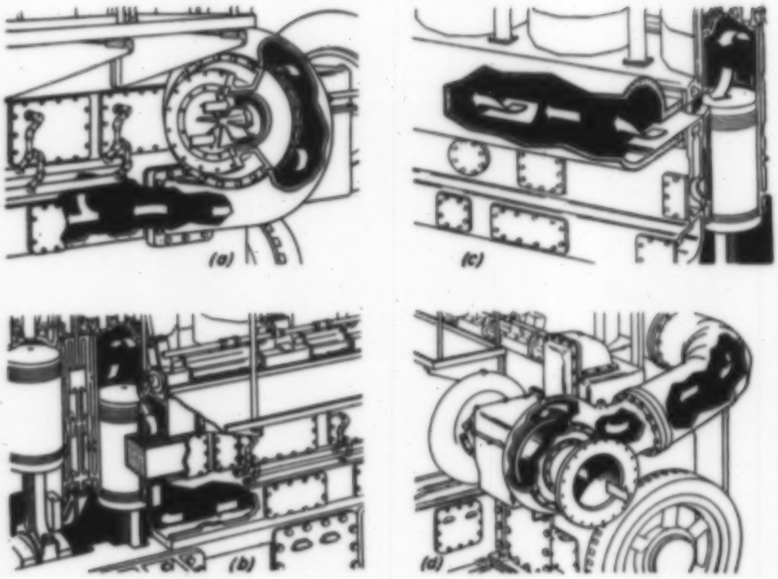

Fig. 1—Details of turbocharger show: *a*—impeller pumping air into main scavenging air passage; *b*—scavenging air passing through intercooler and entering cylinder; *c*—exhaust gases leaving cylinder through exhaust manifold; and *d*—exhaust gases at elevated pressures actuating turbine, which in turn drives the impeller

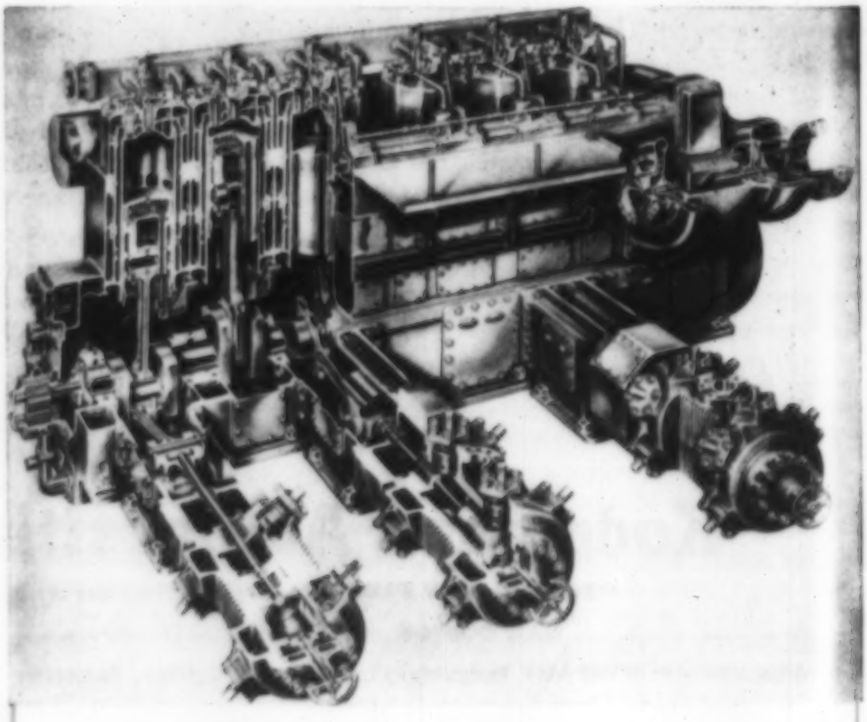

Fig. 2—Two-stroke pumping engine with built-in turbocharger at right end

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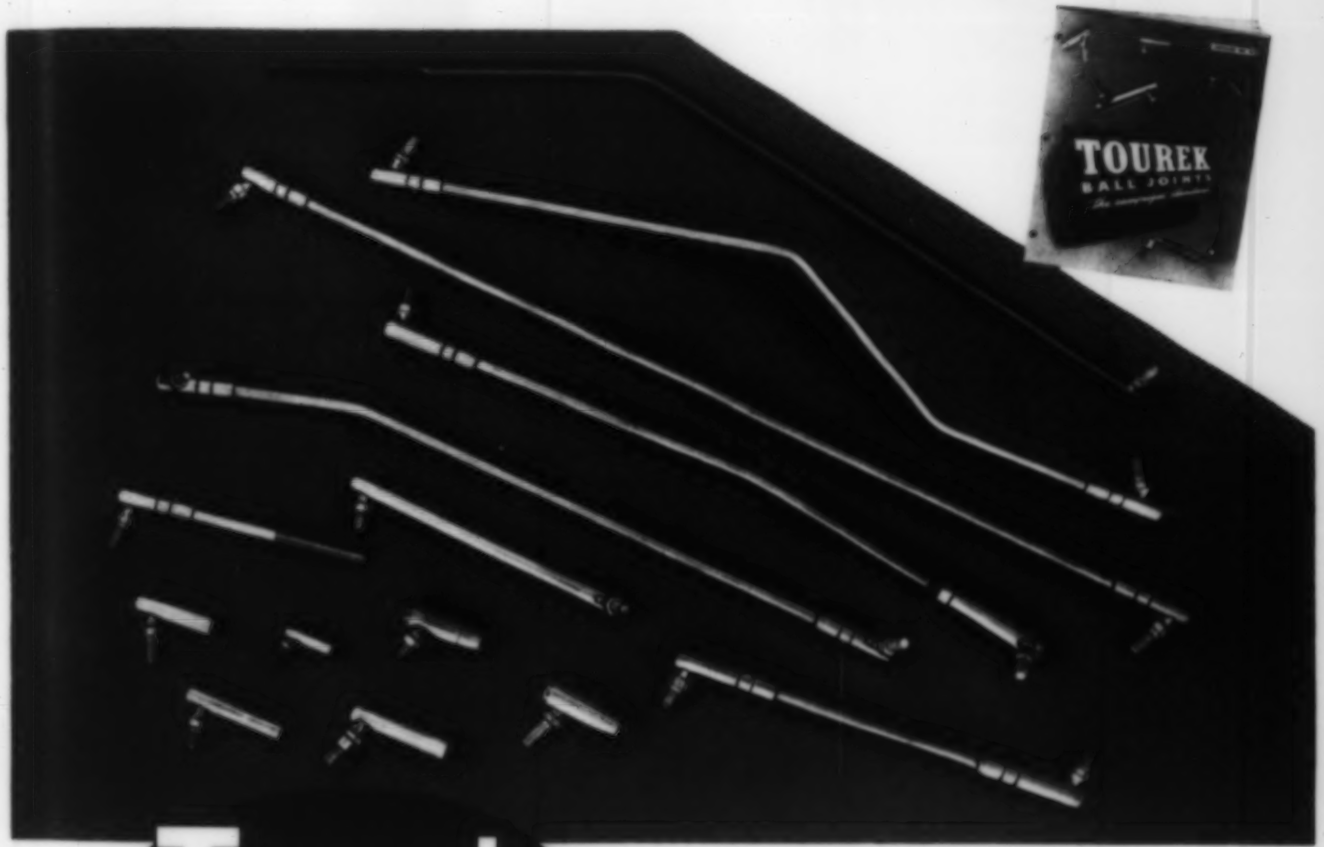

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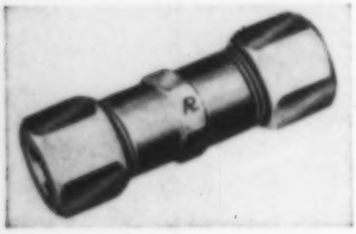
For additional information on these new developments, see Page 217

Tube Fitting

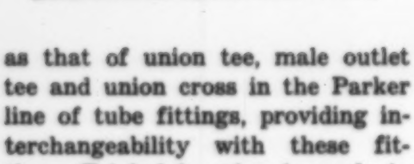
New long union is available in both the Triple-lok flare type and the Ferulok flareless type (illustrated). Overall length is the same as that of union tee, male outlet tee and union cross in the Parker line of tube fittings, providing interchangeability with these fittings. Triple-lok union is made in brass, steel, type 316 stainless and aluminum; Ferulok, in steel and stainless. Both types are available in sizes to fit 1/8 to 2-in. OD tubes. Made by Tube and Hose fittings Div., **Parker Appliance Co.**, 17325 Euclid Ave., Cleveland 12, O.



For more data circle MD-68, Page 217

Air-Hydraulic Cylinder

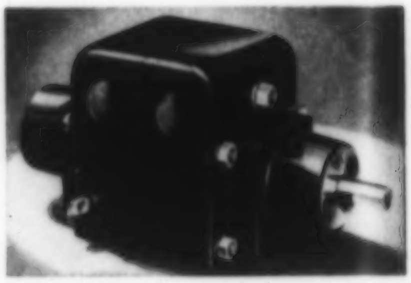
The air cylinder surrounds the oil cylinder in this coaxial air-hydraulic unit. Expanding exhaust air helps cool the oil to provide dependable operation under continuous rapid cycling and heavy loads. Automatic models are available with built-in controls of speed, direction, adjustable fast traverse in either direction and automatic recycling. Remote controls can be provided for automatic models. Standard models can be remotely controlled with conventional valving and piping. Cylinder develops hydraulic piston thrust of 3.14 times air line pressure and pull of 2.7 times air line pressure. It is available in any stroke length to 72 in. and can be used with any standard Modernair cylinder mounting. Made by **Modernair Corp.**, 400 Preda St., San Leandro, Calif.



For more data circle MD-69, Page 217

Synthetic Rubber Pump

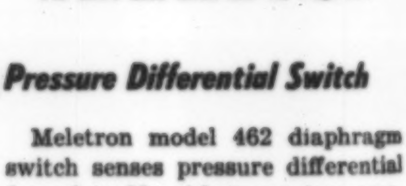
Positive - displacement, oscillating rotary type pump is designed for turbulence-free pumping of chlorine-bearing fluids, acids, alkalies and organic and inorganic chemicals compatible with its synthetic rubber body. Boiling hydrochloric, sulphuric and mixed acids can be handled by pump equipped with Hastelloy-B shaft, eccentrics and guides. With these parts made of Hastelloy-C, service is extended to handling highly oxidizing agents. Capacities up to 10 gpm and pressures to 100 psi are realized at a sustained 1725 rpm. Impellers of the self-priming pump are of DuPont Neoprene, Hypalon or Teflon. Made by **Eco Engineering Co.**, 12 New York Ave., Newark 1, N. J.



For more data circle MD-70, Page 217

Pressure Differential Switch

Meletron model 462 diaphragm switch senses pressure differential from 0 to 99 psi between two pressures within working range of 0.05 to 100 psi. Unit will actuate an electric circuit on increase or decrease of predetermined pressure differential within its range. Differential is adjusted by ratchet. Switch operates in any position without need for balancing or leveling and is unaffected by jarring or vibration. Snap-action, single-pole, double-throw switching ele-



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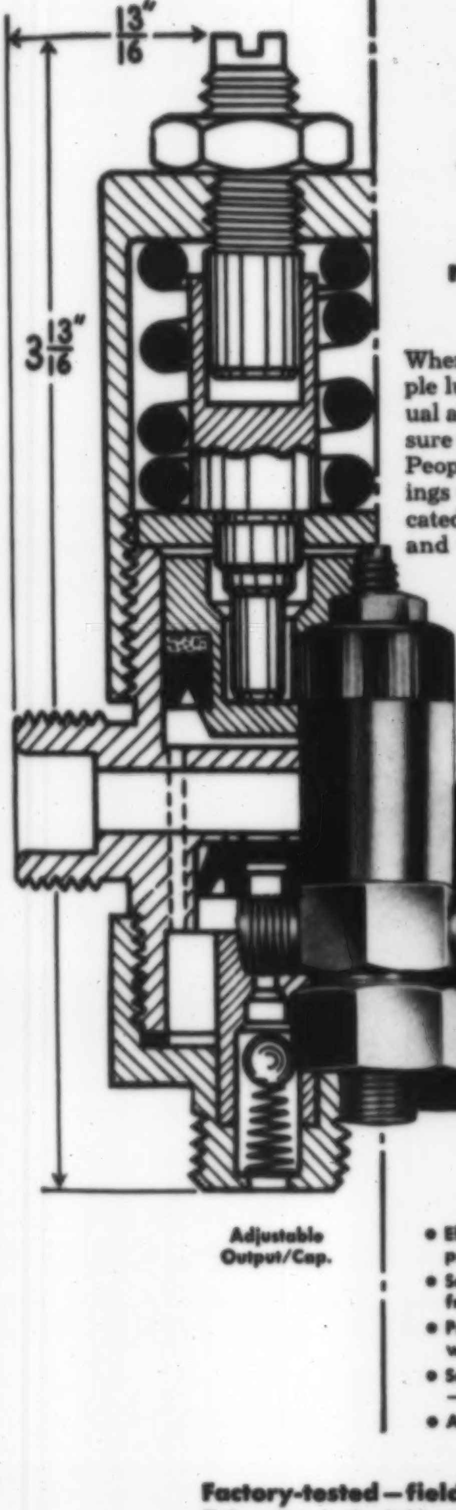

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When a machine is designed with multiple lubrication fittings that require manual attention, the user of that machine is sure to encounter a number of problems. People being what they are, some bearings will be neglected, others over-lubricated. Further, hand lubrication is costly and valuable production time is lost when machines must be shut-down for lubrication.

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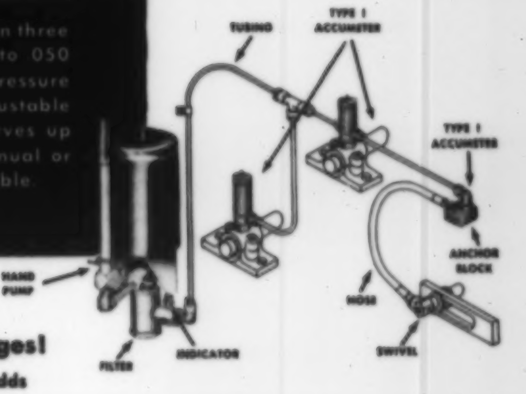

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ment rated for ac and dc circuits will operate relays, solenoids, motor controls and similar devices. Accuracy is within ±1 per cent of setting. Made by **Barksdale Valves,** 5125 Alcoa Ave., Los Angeles 58, Calif.

For more data circle MD-71, Page 217

Thumb Nuts and Screws

Die-cast zinc alloy thumb nuts and screws with wide heads and smooth, rounded scalloped edges are easy and comfortable to grip. Fasteners are corrosion resistant and, although usable without protective finish, are available in all commercial finishes. Three standard head diameters are offered in open or closed end thumb nuts and thumb screws with or without shoulders. All standard thread sizes are available; special sizes or design variations can be made. Made by **Gries Reproducer Corp.,** 400 Beechwood Ave., New Rochelle, N. Y.

For more data circle MD-72, Page 217

Miniature Vibration Isolators

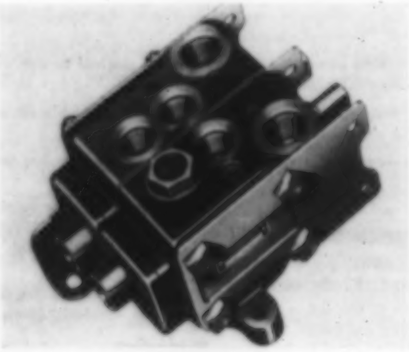
Miniature All-Metal vibration mounts meet military specifications, including ability to maintain damping and isolation effectiveness at extreme temperatures. Mount contains a stainless steel spring which supplies the resilience and deflection necessary for isolation in supporting the load. A formed wire mesh snubber cushions those shocks which are large enough to bottom the load-carrying spring. The snubber is effective in all directions in preventing the aluminum core from hitting the mount's outer shell. Available in four series with load ratings ranging from 0.9 to 3 lb, mounts differ in the location of the mounting plate and in the number of mounting holes. Effective height of series M-22 and M-24 is 1 in.; effective height of series M-21 and M-23 is ½-in. Made by **Barry Corp.,** 700 Pleasant St., Watertown 72, Mass.

BARRY MOUNT

For more data circle MD-73, Page 217

Multiple Unit Valves

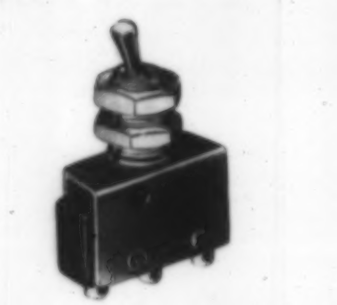
Composed of as many as eight standardized and interchangeable units assembled between compact combination inlet and outlet units, series CM 11 valves meet requirements of heavy-duty mobile equipment applications. Inlet section is a single casting that combines inlet manifold, operating valve and relief valve. Outlet unit is also a one-piece casting combining outlet manifold, operating valve and end plate. Individual end plates are available for applications involving the use of a single operating valve. Double and single-acting operating valves are available, the latter designed for either direction of lever shift. Joints between mating faces of valve sections are sealed with O-rings. Maximum working pressure is 2000 psi; pressure drop through the valve is 50 psi. Made by **Vickers Inc.,** 1400 Oakman Blvd., Detroit 32, Mich.



For more data circle MD-74, Page 217

Miniature Toggle Switch

Smooth operation, long life and positive detent action are exhibited by this precision miniature toggle switch. Except for the beryllium-copper spring, all parts of the toggle actuator are stainless steel. Switch component consists of E4-3 MIL approved basic switch. Contacts are single-pole, single or double-throw, normally open or normally closed. Electrical rating is 5 amp, 125 or 250 v ac or 4 amp, 30 v dc resistive. Made by **Electro-Snap Switch & Mfg. Co.,** 4218-30 W. Lake St., Chicago 24, Ill.



For more data circle MD-75, Page 217

Subminiature Motors

Planetary gear reduced motors measure ⅞-in. in diameter and vary in length from 2½ to 3 11/64 in., depending on speed reduction ratios. Smallest model weighs 5 oz. Unit consists of an SS Moto-Mite permanent-magnet dc motor and a system of high-precision machined planetary gearing. Nineteen standard reduction ratios are available. Speed governors can be fur-

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○ Lord J-6221-2 Flat Bonded Long Pads used on the connecting rods.

☆ Lord J-6222-1 Flat Bonded Rebound Pads used on the connecting rods.

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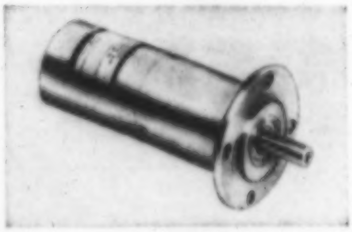
nished for applications requiring close speed control; standard or custom mounting flanges can be supplied; and separate radio noise filters are available. Motors meet all applicable military specifications, including high and low temperature requirements and complete environmental protection requirements. Made by **Globe Industries Inc.**, 1784 Stanley Ave., Dayton 4, O.



For more data circle MD-76, Page 217

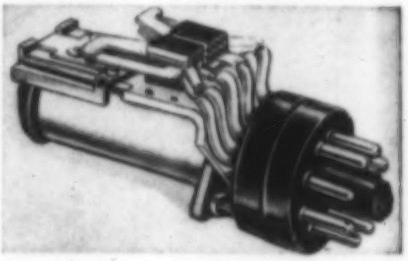
Cam Clutches

Indexing, overrunning and backstop functions can be served by PB series of plain bearing cam clutches. Units are used in conjunction with standard shafting on press feeds, two-speed drives and as backstop and overrunning clutches in machine drives. They have long bronze bearings, hardened and ground steel inner and outer races, full complement cam and energizing spring assembly, a snap ring and a grease fitting. Seven standard sizes range from 2-in. OD by 2 in. long to 5¼-in. OD by 4⅜ in. long. Smaller units operate at 1500 rpm maximum; larger units at 800 rpm. Smallest and largest models are rated respectively at 8.2 and 545 lb-ft, indexing; 16 and 1075 lb-ft, general duty; and 23 and 1584 lb-ft, backstop. Made by **Morse Chain Co.**, 7601 Central Ave., Detroit 10, Mich.

For more data circle MD-77, Page 217

Plug-In Relay

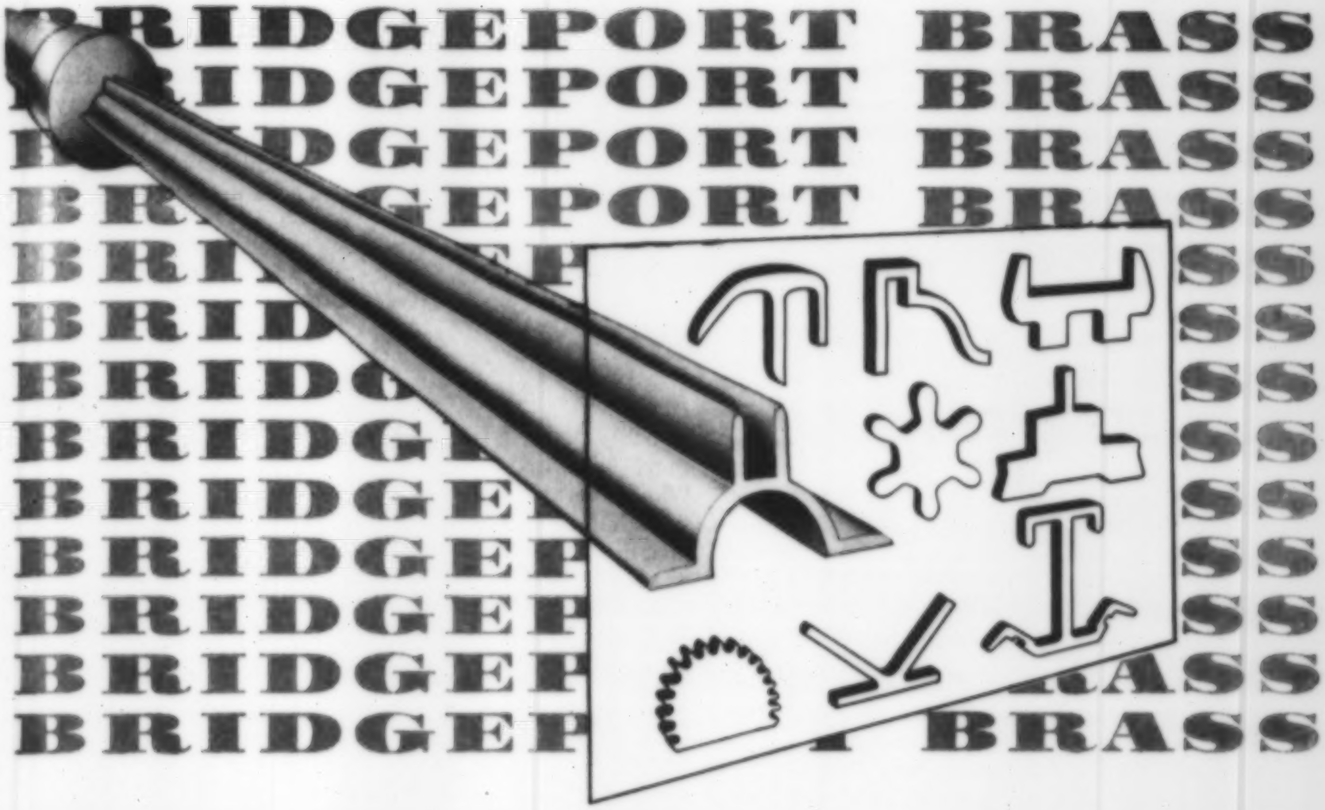
Installation, inspection or replacement of relays without disturbing wiring is possible with this open type plug-in unit. When used in portable equipment, the relay can be removed readily for protection in transit. It can be furnished with standard contact combinations up to 24 arms. Standard contact ratings are 2 amp at 24 v dc or 115 v ac. Bifurcated contacts for extremely low voltage and low-current or heavier contacts rated up to 5 amp can be furnished. Operating voltages available range from 6 to 230 v ac or dc. Made by **Magnecraft Electric Co.**, 1442-M W. Van Buren St., Chicago 7, Ill.



For more data circle MD-78, Page 217

Sliding Latch

Hinged or removable doors and panels can be drawn up tight against their frames or gaskets by turning knob of this sliding latch. Adjustable pawl pressure applied by turning threaded knob eliminates rattling and seals against dust and water. Latch can be installed entirely on outer surface of door and frame by four rivets or screws, and only the heads of these fasteners project through to the inside. Where more space is available inside door, an alternate model conceals all parts but the knob behind the door



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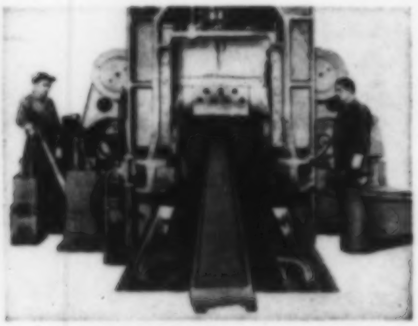

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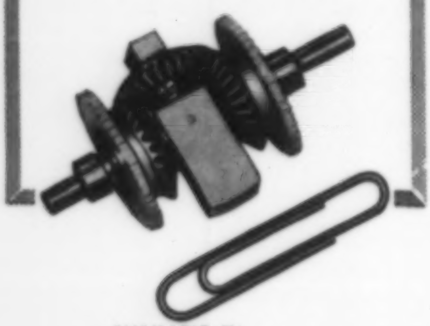

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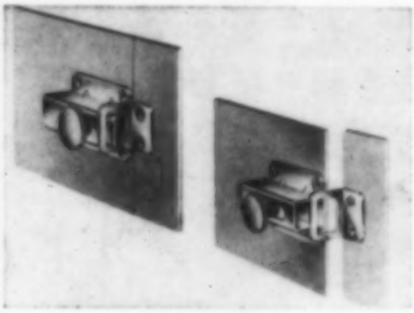


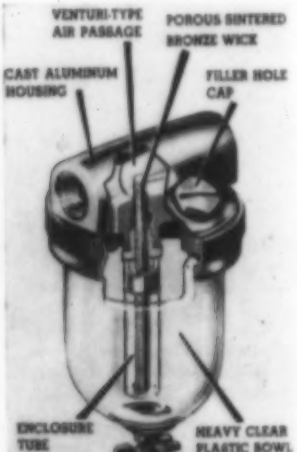
surface. This model requires no striker, since pawl slides behind door frame. Wide tolerances of latch facilitate installation and allow for variations in panel thickness up to ¼-in. Made by Southco Div., **South Chester Corp.**, Lester, Pa.

For more data circle MD-79, Page 217

Air Line Lubricator

Improved air line lubricator has porous sintered bronze wick with clear plastic enclosure tube which provides a high oil feed range. A low range is provided with tube removed. Further variations are obtained by adjusting wick height. Two orifice inserts furnished with lubricator can be used to reduce rated air capacity for low air-flow applications. Large hole insert provides normal oil feed when air is flowing at 75 to 80 per cent of capacity with no orifice insert, while smaller hole insert provides oil feed at 35 to 40 per cent of normal air flow. Wick enclosure tube allows use of oils from light spindle type through SAE No. 10, including rust inhibiting types. Made by **Keller Tool Co.**, 1333 Fulton St., Grand Haven, Mich.

For more data circle MD-80, Page 217



Solenoid Air Valve

Compact Hi-Cyclic air valve is solenoid valve-piloted by full line pressure. It is capable of high actuation rates and will operate on short electrical signal, with short reaction time. A double solenoid model (illustrated), as well as a single solenoid, spring return model are available. Three or four-way valves are made in ⅛, ¼, ⅜ and ½-in. modified NPT sizes, for operation on dc voltages from 1.4 to 475 and ac voltages from 3.6 to 750 at 25, 30, 40, 50 or 60 cycles. Valves are equipped with a ½-in. NPT electrical conduit outlet. They also can be supplied with high-temperature coils, as well as explosionproof housings. Made by **Beckett-Harcum Co. Inc.**, 1087 Wayne Rd., Wilmington, O.

For more data circle MD-81, Page 217

Pressure-Actuated Switches

Small, explosionproof switches for leakproof sensing of pressure in pneumatic, hydraulic, fuel and oil systems weigh approximately 4 oz. They are adaptable to any mounting or envelope requirement; calibration is not affected by mounting position. Switches operate in pressure range of 5 to 12,000 psi. They withstand surge pressures to 7500 psi at 30 cycles

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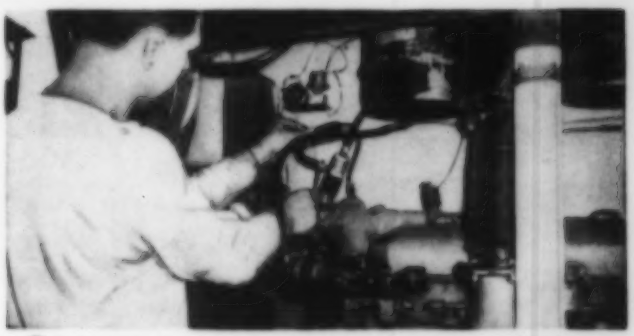
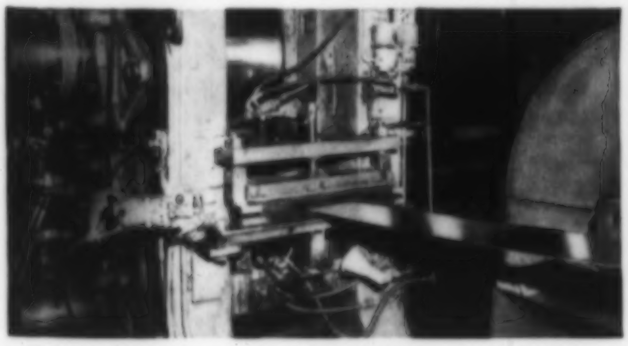


● **Albert Schardl, maintenance foreman, New Britain Transportation Company, Inc.: "Aeroquip has prevented road failure due to hose breakage. Within the next six months we expect to be 100% Aeroquip . . ."** (*Bus operators*)



● **Peter Wallace, maintenance superintendent, Wallingford Steel Company: "Aeroquip is better because of quick installation. It stands continuous abuse and increases safety."** (*Operators of steel rolling equipment*)

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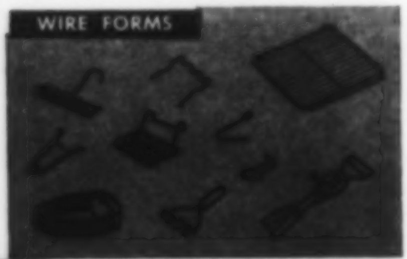

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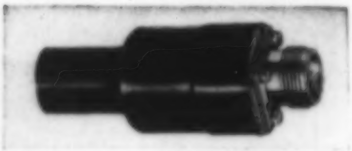
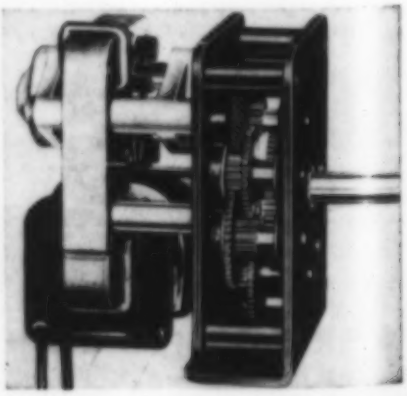
per minute. Operating at temperatures from −65 to 275 F, they maintain sensitivity ranging from ±3.5 per cent at 3000 psi to ±10 per cent at 100 psi. Switches withstand 25 *g* vibration at 2000 cycles per second. Contacts are single or double-pole, single or double-throw and normally open or normally closed. Rating is 17 amp inductive at 24 v dc, 15 amp at 115 v ac, and 7.5 amp at 230 v ac. Made by Leach Relay Co., Div of **Leach Corp.,** 5915 Avalon Blvd., Los Angeles 3, Calif.



For more data circle MD-82, Page 217

Gearmotor

Business machines, appliances and vending machines are among potential applications for quiet-running model MD gear train and motor combination. Torques ranging from 60 lb-in. at 1 rpm to 50 lb-in. at 10 rpm (1/300 to 1/35-hp) and any single speed from ¼ to 426 rpm are available. Rotation can be in either direction as specified. Gears, pinions and shafts are hardened steel, bearings are bronze, and lubrication is provided by a large felt oil reservoir. Provision is made for panel or base mounting in both open and enclosed models. Shaded-pole motor operates on 115-v, 60-cycle ac



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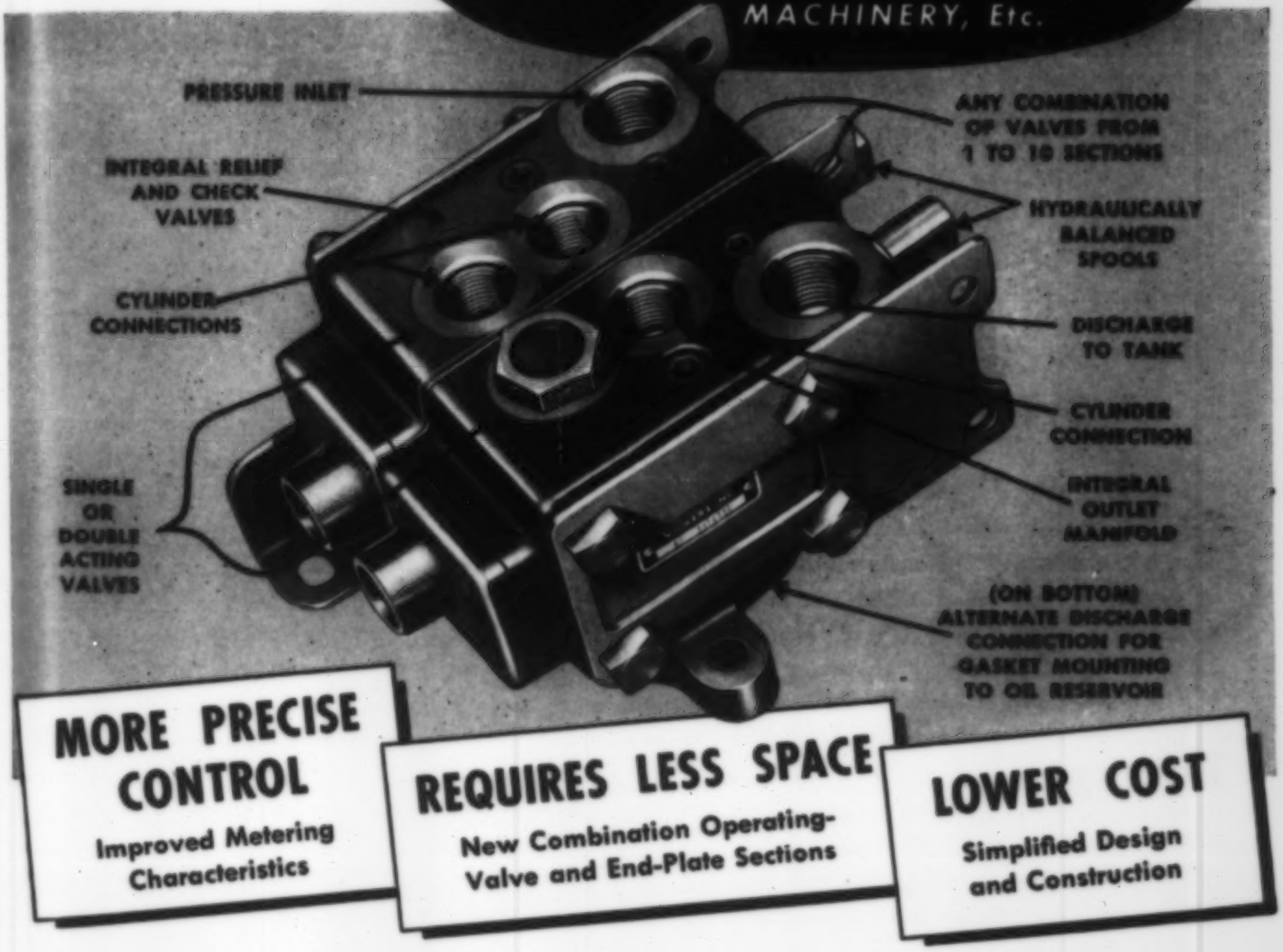
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Other features include protection of pump from reverse flow during shifting . . . three point mounting for more simple installation . . . cylinder connections with ¾-16 N.F.-2 straight threads (AND 10050 type) which conform to SAE standards help insure leak-proof connections . . . optional outlet ports in end section so valve can be gasket mounted to the oil reservoir or pipe connected. Designed for use with Vickers Series V-200 Vane Pumps (up to 11 gpm), the CM11 Valve can be used up to 2000 psi working pressure. For further information write for Installation Drawing M168643.

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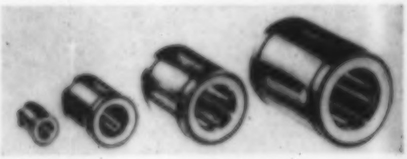
For more data circle MD-83, Page 217

Linear Bearing

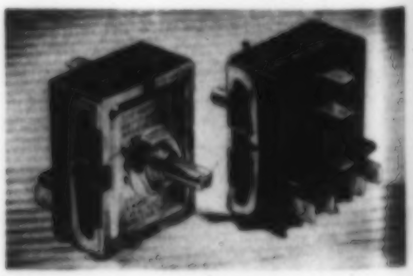
Shaft diameters of ¼, ½, ¾, 1, 1½, 2, 2½ and 3 in. can be fitted with stainless steel Ball Bushings for linear motion in corrosive liquids or atmospheres. Capable of dry operation at slow and moderate speeds, units are free rolling to practically eliminate friction and preclude binding and chatter. Low friction coefficient of 0.002 to 0.004 practically eliminates wear. Made by **Thomson Industries Inc.**, Manhasset, L. I., N. Y.



For more data circle MD-84, Page 217

Rotary Heater Switches

Diamond H series 910 rotary heater switches for two and three-wire systems have spade terminals to facilitate wiring and extensible spindles to control gears, dampers, other switches or accessories with one dial. Design of bases permits use of two, four or six dummy spade terminals to eliminate need for separate terminal blocks. Single or double-pole switches have from two to ten positions



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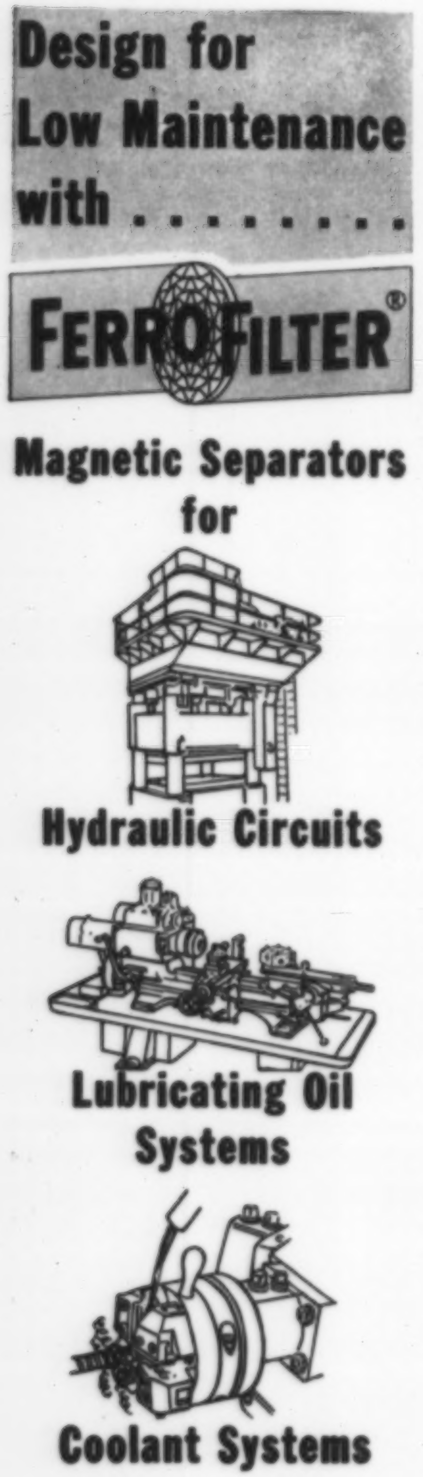
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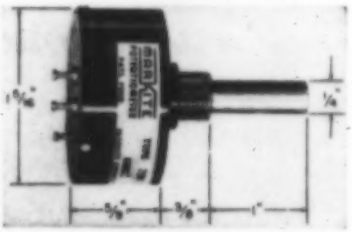
(off-on, three to nine heats), and may also be had with special circuit variations and motor-rated circuits. Standard ratings include 15 amp, 120-240 v; 20 amp, 1 hp, 120 v, 2 hp, 240 v; ½, ¾, 1 hp, 120 v; 1, 1½ and 2 hp, 240 v, ac only; low dc and special ratings are also available. Switch bases measure 1 27/32 x 1 21/32 x ⅞-in. Spindle lengths, including spindle extensions, can be varied as required. Made by **Hart Mfg. Co.**, 110 Bartholomew Ave., Hartford, Conn.

For more data circle MD-85, Page 217

Rotational Potentiometer

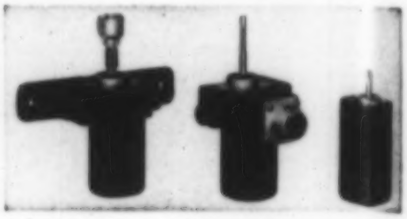
Type 2094 potentiometer is designed for applications requiring long life, substantially infinite resolution and low noise under extreme vibration and acceleration. It will perform 5 million revolutions at maximum speed of 600 rpm. Active element is a solid resistance track of conductive plastic which is integrally co-molded, with terminals and center tap contacts, to a rigid phenolic insulator support. Torque is less than 0.5 oz-in. Standard resistance values of 2000 to 100,000 ohms with linearity of 0.5 or 1 per cent are available. Power rating is 2 w at 20 C. Made by **Markite Corp.**, 155 Waverly Place, New York 14, N. Y.



For more data circle MD-86, Page 217

Miniature Electric Motors

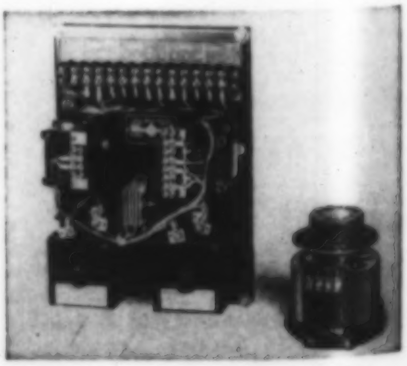
Miniature electric motors for use in actuators or other high-speed applications are offered in three styles. Split series type, 24-v dc or 110-v ac No. 452008 motor (shown at left) is rated 2.5 oz-in. for intermittent duty to 160 F. It is available for unirotational and reversible operation, with or without an integral filter. Motor No. 406046 (in center) is shunt field type, 24-v dc unit for unirotational operation only. It is rated 1 oz-in. for continuous duty to 160 F. Split series, 24-v dc, square type motor No. 1007690 (shown at right) is rated 4 oz-in. for intermittent duty to 165 F. It is available for unirotational or reversible operation and with or without magnetic brake. Made by **Bendix Aviation Corp.**, Pacific Div., 11600 Sherman Way, North Hollywood, Calif.



For more data circle MD-87, Page 217

Motor Speed Controls

Variac motor speed controls in sizes from 1/15 to 1½ hp are now available in stripped-down form for assembly into various types of equipment. They provide for operating dc shunt or compound motors from ac power lines. All parts except speed control element are mounted on a metal chassis with connections brought out to a terminal strip. Various circuit arrangements can be used, depending on need for reversing, dynamic braking or other variations, but only the Variac element and switches need be at the control

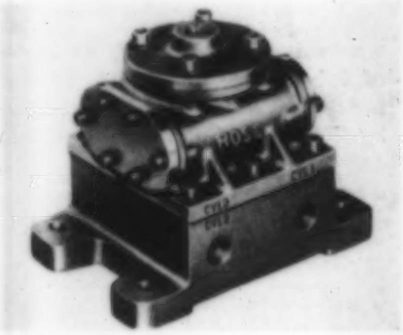


point. Controls offer wide speed range, smooth adjustment, high starting torque, quick reversing, no torque pulsation and smooth starting. Made by **General Radio Co.**, 275 Massachusetts Ave., Cambridge 39, Mass.

For more data circle MD-88, Page 217

Remotely Controlled Valve

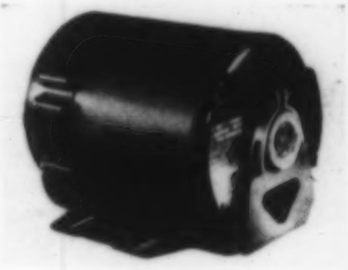
Retrold valve is a four-way, base-mounted, pressure - operated model controlled by air from a remote pilot valve which may be hand, foot, cam or solenoid-actuated. Both actuation and reversal are immediate. Standard models include side ports, ¼ through ¾-in. pipe sizes. The 1 and 1¼-in. sizes are bottom ported. Maximum main valve pressure is 125 psi; pilot air pressures may be equal to or greater than main valve pressures, but not less than 30 psi. Operating temperature limit is 175 F. Made by **Ross Operating Valve Co.**, Dept. R3101, 120 E. Golden Gate, Detroit 3, Mich.



For more data circle MD-89, Page 217

Fractional-Horsepower Motor

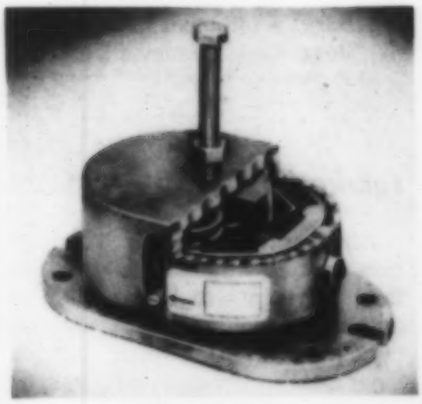
Totally - enclosed, split - phase fractional horsepower motor is smaller and one-third lighter than previous designs. The fan-cooled motor operates dependably and continuously under severe conditions of dust and dirt. Large-size ball bearings absorb heavy thrust loads and require no lubrication for ten years of normal service. In NEMA frame sizes 48 and 56, motor is available in ratings of 1/6-hp at 1140 rpm to ⅓-hp, 3450 rpm, 60 cycles. Fifty-cycle models are also available. Mounting dimensions are the same as for standard open motors of the same rating. Made by General Purpose Component Motor Dept., **General Electric Co.**, Schenectady 5, N. Y.



For more data circle MD-90, Page 217

Vibration Mountings

Steel spring mounting of type SF vibration isolator permits deflections necessary for high efficiency. Semi-steel housings of telescopic construction provide complete enclosure of all working parts. Resilient guides contained within upper portion of housing offer all-direction snubbing and damping. Combination adjustment and leveling bolt is provided for loading springs and leveling isolated equipment, as is a locknut for securing machine base. Factory preset, mounts may be adjusted in the field. Typical applications are for use on rotating and reciprocating machinery such as punch presses,



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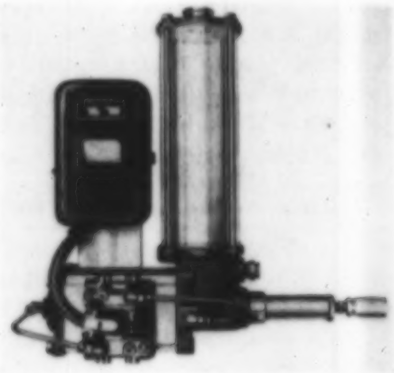
For more data circle MD-91, Page 217

Counting Device

Applicable to any rotating device of 3600 deg or less, the model 1301 Microdial is a direct-reading, precision counting dial for manual or servo-motor-operated multiturn devices. Shaft or wiper position is indicated numerically in complete turns and tenths and hundredths of turns. Dial is calibrated to an accuracy of 1 part in 1000. Reading error is only 0.2-per cent on forced fast reading tests. Device can also be used as a percentage counter, since it indicates increments of 0.1-per cent. Control knob is tapered and fluted. Setting and braking is done with one hand. Dust-sealed dial is 2 in. diameter and 1⅝ in. high. Made by Borg Equipment Div., **George W. Borg Corp.,** Janesville, Wis.

For more data circle MD-92, Page 217

Lubrication System

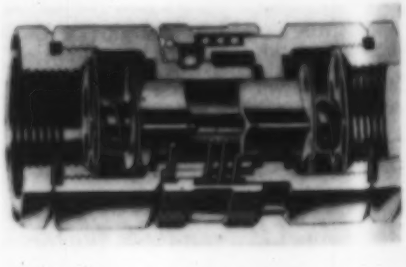


Air-operated centralized lubrication system automatically applies fluid lubricants to bearings on individual machines at predetermined intervals. System services machines operating at varying rates of speed where applications of lubricant at varying intervals may be required and also lubricates automated machine lines. Control may be manual; mechanical, utilizing motion of the machine to actuate an air valve which in turn cycles the lubrication system; or electrical, utilizing an adjustable time clock to actuate a solenoid air valve which cycles the lubrication system at intervals of 7½ minutes to 3 hours. Clear plastic lubricant reservoir holds 5 pt. Two models of lubricator have lubricant outputs of 0.9 and 2.7 cu in. Made by **Lincoln Engineering Co.,** Industrial Div., 5736 Natural Bridge Ave., St. Louis 20, Mo.

For more data circle MD-93, Page 217

Quick-Disconnect Coupling

Improved H series quick connect-disconnect coupling is suitable for high pressure and heavy surge applications. It is available in sizes of ⅛ to 10 in. ID. Metal-to-metal valve stop in closed position permits positive control of compression of valve washer sealing member regardless of the surge or pressure build-up in line. A barrel spring, with perforated "spider," full circle valve stop and guide, holds valves steady in open position, allowing no valve float. Spring permits high pressures and surges in both directions through coupling or even rapidly pulsating surges in both directions. Couplings are standard in high tensile



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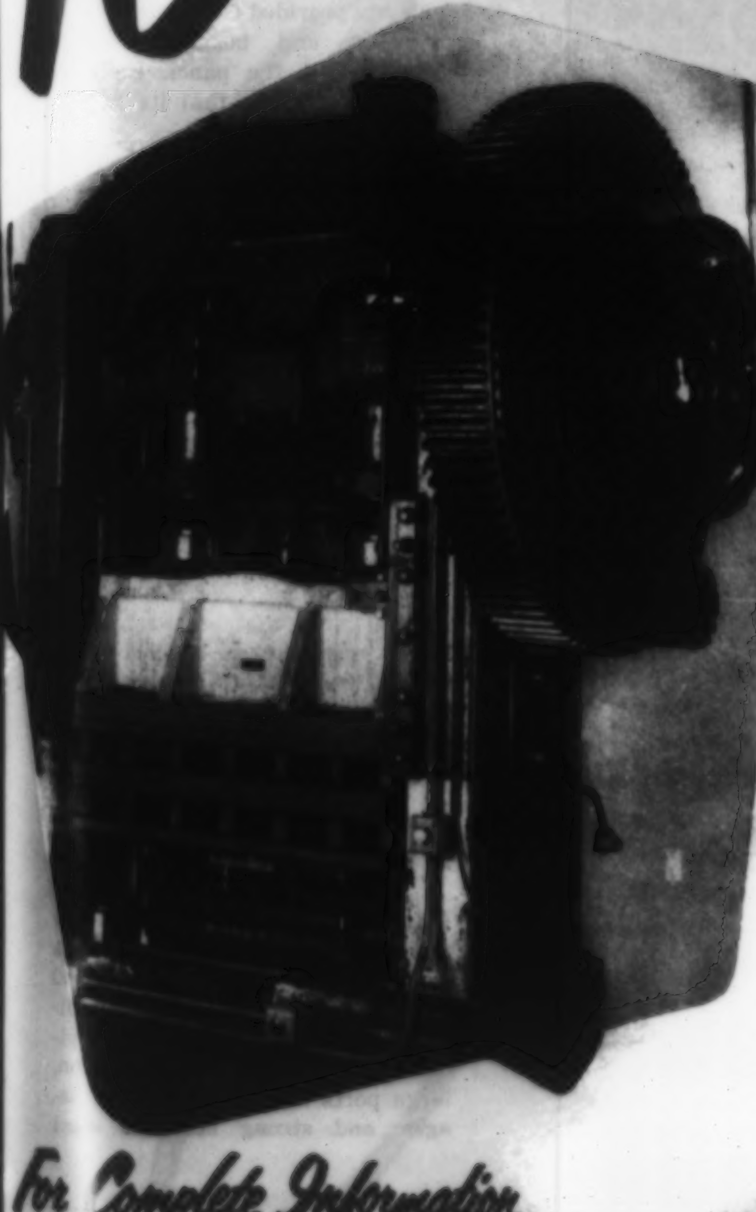

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strength alloy steel but can be furnished in stainless steel and nonferrous materials. Made by **Snap-Tite Inc.,** 201 Kelly St., Union City, Pa.

For more data circle MD-94, Page 217

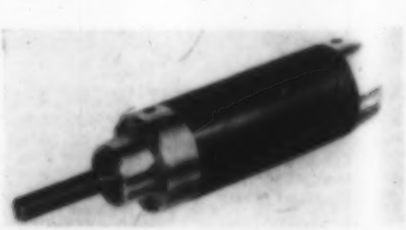
Subminiature Pilot Lights

Socket, lamp and all connections are well insulated from the 15/16-in. diameter mounting bushing of this line of Dialco subminiature pilot light assemblies. Two terminals are provided for electrical connections, and bushing can be grounded to the panel. Bulb extends into cap so that its glow is visible from all angles. Heat-resistant plastic cap can be transparent, light diffusing or completely diffusing in clear or any of six colors. All metal parts are brass, finished in black nickel, white nickel, or chrome. Terminals are perforated for wire and tinned to facilitate soldering. Series employs any of five standard miniature flanged base incandescent lamps of 1.3, 2.7, 6.0, 14.0 and 28.0 v. Made by **Dialight Corp.,** 60 Stewart Ave., Brooklyn 37, N. Y.

For more data circle MD-95, Page 217

Hydraulic or Pneumatic Cylinder

Lightweight Power Drive cylinder can be operated at pressures to 500 psi with oil or water or 200 psi with air. Bore diameters available are 1½, 2¼, 3 and 4 in. Cylinder has sealed-in lubrication, large ports and unrestricted passages, and strong stainless steel



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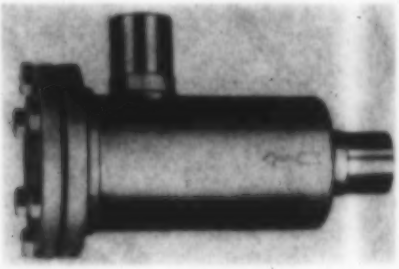
piston which is ground and polished to provide long life for rod seal, bearing and wiper. The gland, consisting of wiper, Oilite bearing and self-compensating packing, can be replaced without dismantling the cylinder. Foot, flange, pivot, clevis or trunnion mountings are interchangeable. Made by Industrial Actuators and Controls Div., **National Pneumatic Co. Inc.**, 125 Amory St., Boston 19, Mass.

For more data circle MD-96, Page 217

Strainers

Fabricated of ferrous and nonferrous metals for use with various fluids, strainers for protecting valves and pumps in all fluid systems are offered in cleanable and noncleanable models. They are built with reinforced Monel and stainless steel screens of 60 and 80 mesh, with up to 180 sq in. of screen area. Finer meshes can be furnished. Strainers are available with connection sizes up to ⅝-in. SAE, 3⅝ in. sweat and 1½ in. FPT with flange. Made by **Detroit Controls Corp.**, 5900 Trumbull Ave., Detroit 8, Mich.



For more data circle MD-97, Page 217

Time Delay Relays

Hermetically sealed relays have provision for adjustment of the time delay period. The timer, which is totally enclosed in the hermetic housing, can be adjusted after sealing by means of a knurled knob. Adjustable in small increments over a range of 8:1, the unit can be supplied with delay intervals ranging from 2 seconds to 2 hours. The large

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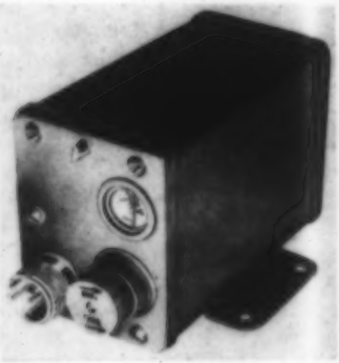
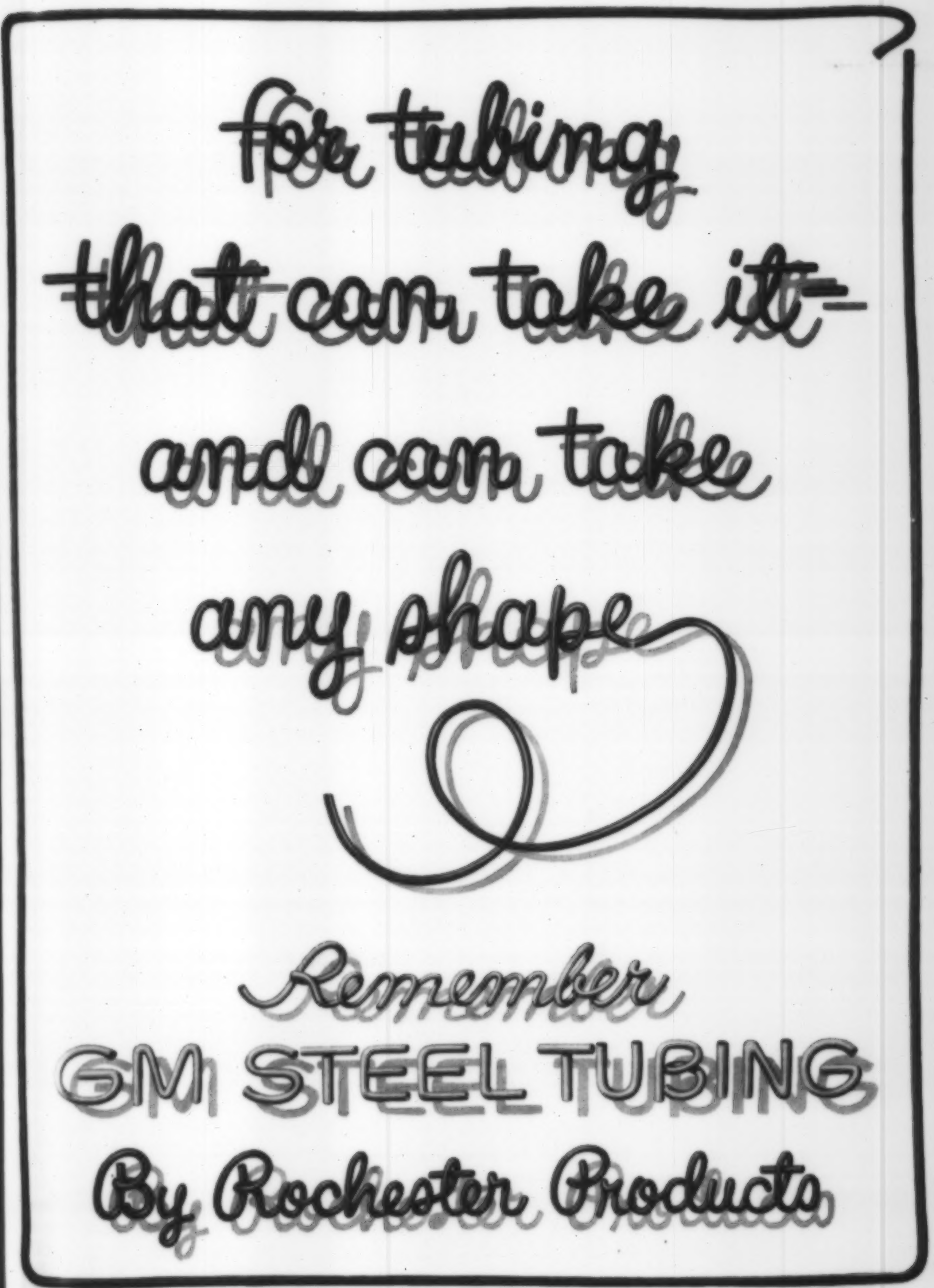


calibrated dial is read through a glass window. Units meet military specifications and can be supplied for operation on dc or ac power supplies. One or more switches can be incorporated, and electrical connection can be made with either an AN connector or a glass-metal header. Bracket or stud mounting is available. Made by **A. W. Haydon Co.,** 221 W. Elm St., Waterbury 32, Conn.

For more data circle MD-98, Page 211

Electric Cable Reel

Electrical power supply cables are fed and rewound quickly and are protected from tangling and wear by series 3 Spring-O-Matic Powereel. The continuous heavy duty cable reel has a compact retractable spring which works automatically as equipment moves. Collection ring is protected against dust and moisture. Reel is available with plain or pivot base, latter permitting swivel through a 330-deg arc. It will accommodate springs of various sizes, making reel adaptable for balancing,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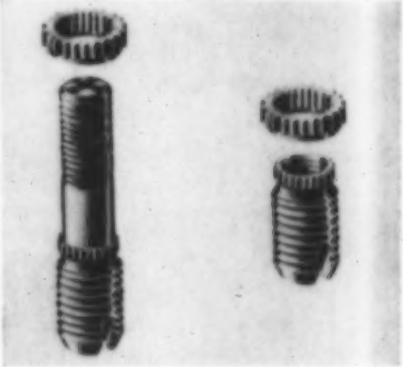
hose or similar applications. Operation is based on 30 amp, 600 v ac, 300 v dc and one to eight conductor collector rings. Made by **Industrial Electrical Works,** 1503 Chicago St., Omaha 2, Nebr.

For more data circle MD-99, Page 217

Inserts and Studs

These ring-locked inserts and studs are now available with self-tapping threads which prevent collapse of tapping segments during installation. Damage to threads of mating bolts is also prevented. All threads are American National Form. Inserts and studs are made of aircraft quality steels and have maximum torque and pull-out resistance. Made by **Rosan Inc.,** 2091 West Coast Highway, Newport Beach, Calif.



For more data circle MD-100, Page 217

Differential Relays

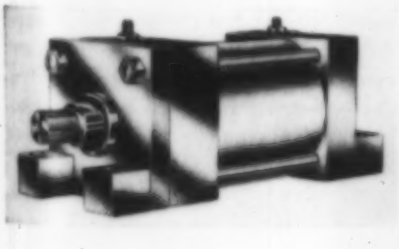
Used for automatic overload, over-voltage, under-voltage or under-current protection, hermetically sealed relays reset automatically when the abnormal condition is corrected. The actuating element is a heater, and the relay can be designed for time constants varying from approximately 3 to 30 seconds. Contacts are single-pole, single-throw, normally open or normally closed. Many circuit variations are possible because contacts are completely isolated. Relays can be designed for currents from 10 to 1000 ma and voltages

from 1 to 100 v. Standard octal or nine-pin miniature bases are available. Standard tolerances of voltage or current for opening and closing is ±10 per cent; closer tolerances can be specified. Made by **Amperite Co., 561 Broadway, New York 12, N. Y.**

For more data circle MD-101, Page 217

Cylinder Mounting

Square lugs that mount flush with Miller square cylinder heads save space in mounting air and hydraulic cylinders. Loads are concentrated close to centerline of cylinder. Designed for side or foot mounting, model 77 is available in complete line of custom cylinders

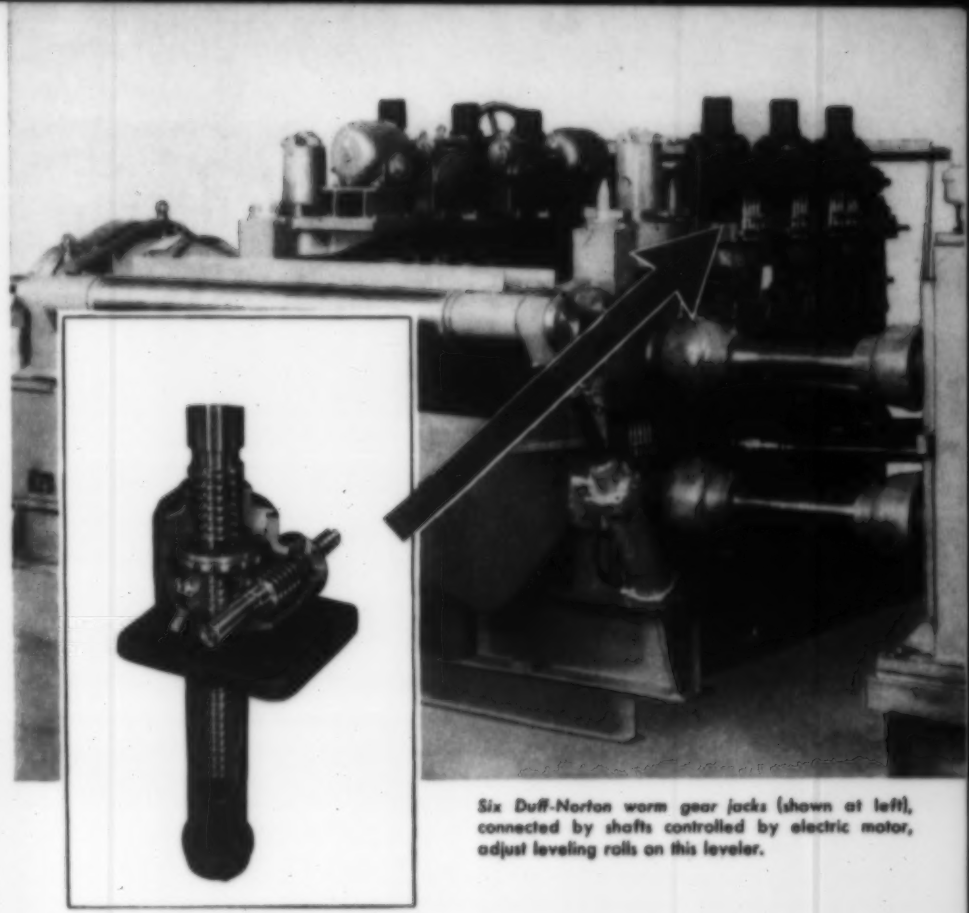


with 1½ to 20-in. bores in 200-psi air cylinders and 1½ to 12-in. bores in 2000-psi hydraulic cylinders. It is also available in all stock cylinders. Made by **Miller Fluid Power Co., 2040 N. Hawthorne Ave., Melrose Park, Ill.**

For more data circle MD-102, Page 217

Fast-Braking Motor

Type PM-4 permanent-magnet motor has an integral brake capable of bringing the armature to a stop within one shaft revolution



Six Duff-Norton worm gear jacks (shown at left), connected by shafts controlled by electric motor, adjust leveling rolls on this leveler.

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It's the Duff-Norton worm gear jack, successfully used by many machine builders as a component of equipment for precise, positive control of linear motion; applying pressure; resisting impact. Two or more of these jacks can be connected by means of shafting and mitre gear boxes or any power-operated positive control system, so that jacks always raise or lower under equal or unequal loads in perfect unison. Capacities range from 5 to 35 tons with any raise up to 25 inches; worm gear ratios, 8:1 to 45:1; turn of worm for each 1 inch raise, 10 to 180; available in either Acme or square threads. Screw ends and tops are available in many types and can be readily adapted to your specific requirements.

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Thus the cores of the teeth and the body of the gear remain ductile and shock-resistant while the teeth are given an increase in service life of over 50%.

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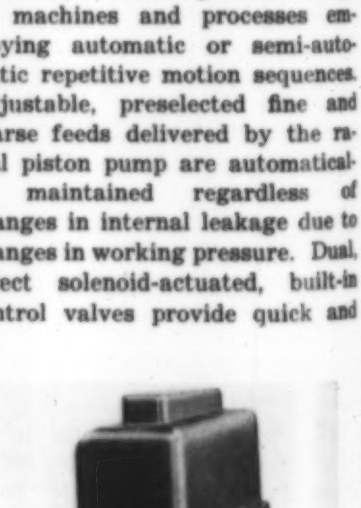
Pittsburgh 25, Pennsylvania

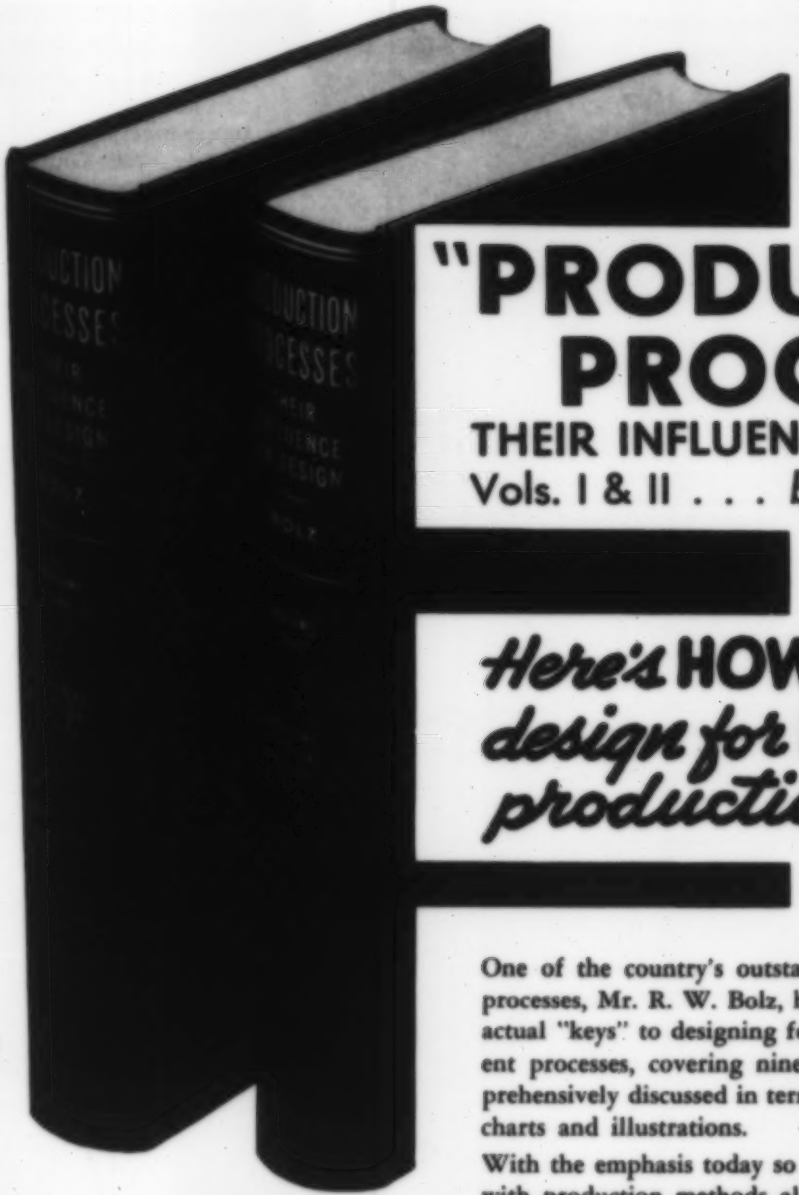
from rated operating speed of 4500 rpm. Motor operates from 28 v dc, and brake is separately actuated, also from 28 v dc. Designed for continuous-duty applications requiring good speed regulation, unit supplies a high starting torque of 50 oz-in. at 10 amp. Standard ratings of 2.5 amp with 40-w load includes 0.25-amp brake current. Dynamic brake torque is 100 oz-in. minimum. Unit has reversible rotation. Made by **Dalmotor Co.**, 1347 Clay St., Santa Clara, Calif.

For more data circle MD-103, Page 217

Variable-Delivery Pumps

Pumps in two sizes provide high rate of feed which remains accurate over a wide pressure range on machines and processes employing automatic or semi-automatic repetitive motion sequences. Adjustable, preselected fine and coarse feeds delivered by the radial piston pump are automatically maintained regardless of changes in internal leakage due to changes in working pressure. Dual, direct solenoid-actuated, built-in control valves provide quick and





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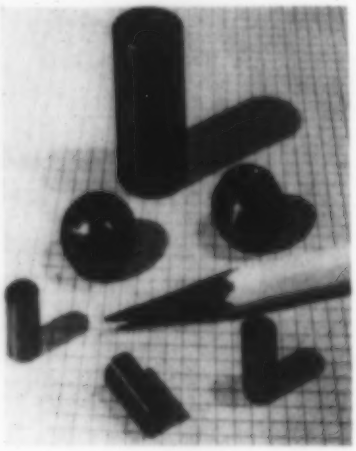
positive control functions in response to remote pushbutton or limit switch control. Drive speeds of pumps range from 710 to 1750 rpm. Feed, at maximum feeding pressure of 1000 psi, ranges from 385 to 950 cu. in. per min. Rapid traverse is provided by built-in gear pump, available in two sizes. Range of rapid traverse is 1300 to 3200 cu in. per min at maximum traverse pressure of 300 psi. Made by **Oilgear Co.,** 1568A W. Pierce St., Milwaukee 4, Wis.

For more data circle MD-104, Page 217

Bearing Material

This bearing material can be used at temperatures from −120 to 500 F. Wear characteristics are good at extreme temperatures. In oil application, material's 40 per cent lubricative solids have oil retention and absorption values which provide wicking action to supply bearing surfaces with lubricative film. Material has ultimate compression strength of 22,700 psi and



can be machined to close tolerances. Made by **Booker-Cooper Inc.,** 6940 Farmdale Ave., North Hollywood, Calif.

For more data circle MD-105, Page 217

Miniature Variable Inductors

Both shielded and unshielded style A, type 1 variable inductors are available in ten standard values from 56 mu h to 1.8 mh and up to a maximum of 25 mh in special units. Inductance variation range is 2 to 1; Q's, approximately 200; operating temperature ranges from —50 to 100 C; and temperature coefficients of inductance are under 50 ppm per deg C. Imbedment of the entire powdered carbonyl-iron cup core and coil assembly in epoxy resin provides high resistance against the effects of large amplitude vibration or shock as well as protection against moisture and chemical attack. Capable of dissipating 2.5 w with a temperature rise of 20 C, units are rated at 400 v max. They measure $1\frac{1}{8}$ in. long and $\frac{3}{4}$-in. diameter. Inductors

are also available in the form of complete sealed tuned circuits with shunt capacitors made to specifications. Made by **Levinthal Electronic Products Inc.,** 2924 Fair Oaks Ave., Redwood City, Calif.

For more data circle MD-106, Page 217

Direct-Drive Fan Motors

Three new direct-drive fan motors have single-point mounting with floating action which minimizes transmission of noise and vibration and simplifies assembly

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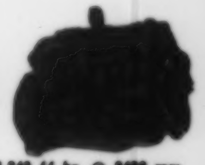
RD-406 175 hp. @ 3200 rpm+
Disp. 405.9 cu. in., 6 cyls.

U-372 95 hp. @ 2200 rpm*
RD 372 165 hp. @ 3200 rpm+
Disp. 372 cu. in., 6 cyls.

U-282 79 hp. @ 2400 rpm
RD-282 137 hp. @ 3600 rpm+
Disp. 282.5 cu. in., 6 cyls.



U-240 66 hp. @ 2400 rpm
SD-240 131 hp. @ 3800 rpm
Disp. 240.3 cu. in., 6 cyls.

U-220 64 hp. @ 2400 rpm*
SD-220 104 hp. @ 3600 rpm+
Disp. 220.5 cu. in., 6 cyls.

U-9 56.3 hp. @ 1500 rpm
Disp. 334.5 cu. in., 4 cyls.

U-264 56 hp. @ 1800 rpm
Disp. 262.9 cu. in., 4 cyls.

U-164 38.5 hp. @ 1800 rpm
Disp. 164 cu. in., 4 cylinders

U-2A 25.8 hp. @ 1800 rpm
Disp. 113.1 cu. in., 4 cyls.

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of the motors into ventilation equipment. Flanges on cast aluminum rotating end bell are tapped to facilitate mounting of individual aluminum blades. Weight of these units is approximately half that of comparable belt-driven fan motors. Overall depth required for mounting the motors is 4½ in. Power rating is 1/12-hp for model SP-60A, ⅛-hp for model S-13E (illustrated), and 1/6-hp for model S-16. Made by **Electric Motors and Specialties Inc.**, King and Hamsher Sts., Garrett, Ind.

For more data circle MD-107, Page 217

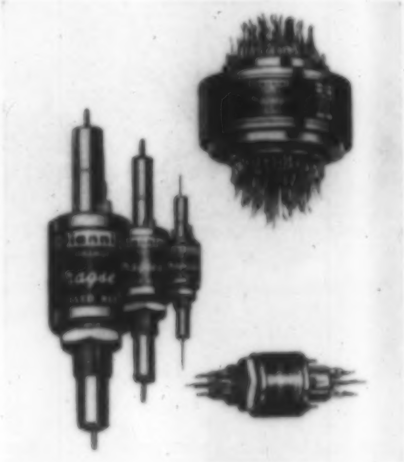
Concentric Shaft Differential

Output and both input shafts extend concentrically from one end of a servo-mounted case in this differential; the two inputs are not located in the usual position at opposite ends of the spider. Differential can therefore be mounted like any standard servo motor, resulting in a single line gear train. All gears and bearings are protected in a dust-tight housing. Mounting of all gears on two high-precision ball bearings results in low break-away torque. Unit is free-running, with minimum backlash. Made by **Trans-American Precision Instruments Corp.**, 34-17 Lawrence St., Flushing 54, N. Y.

For more data circle MD-108, Page 217

Hermetically Sealed Relays

Magseal hermetically sealed contact relays are designed for fast response, high operating speeds, high sensitivity and low capacitance, along with low contact resistance. Two magnetic cylinders enclosed in a sealed envelope contact each other when a magnetic field is brought into close proximity, thus closing a preset gap between the cylinders. Standard relays have the magnetic contacting elements sealed in a glass envelope and are actuated by an electromagnetic coil mounted about the element assembly. Noble metal contacting surfaces are welded onto the elements for low contact resistance and high resistance to corrosion. Sealed case can be filled with atmosphere at pressure or with various inert or reducing gases. Coils can be supplied for constant current or constant voltage applications, and coil specifications can be varied to meet requirements of sensitivity and operating speed. Life expectancy of 1 billion cycles and switching rate up to 60 cycles per second make relays suitable for high-speed switching applications. Single and multiple element units are available. Made by **G. M. Giannini & Co. Inc.**, 918 E. Green St., Pasadena 1, Calif.



For more data circle MD-109, Page 217

Pneumatic Valves

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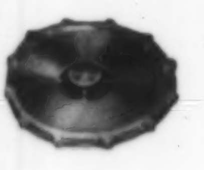
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All Mueller Brass Co. forgings, of which just a few are shown here, have a dense, close-grained structure with a high tensile strength. Weight savings up to 40% are possible in the design of parts because of the close tolerances to which they can be produced. Less scrap and longer tool life result from the easy machinability of forged parts. Mueller Brass Co. is completely equipped to design parts for your products, specify alloys (including special alloys developed by our metallurgists), forge, machine, finish and plate the parts and perform all necessary assembly operations. Write today for our free illustrated 32-page forgings catalog and complete information about MBCo forged parts for your products.

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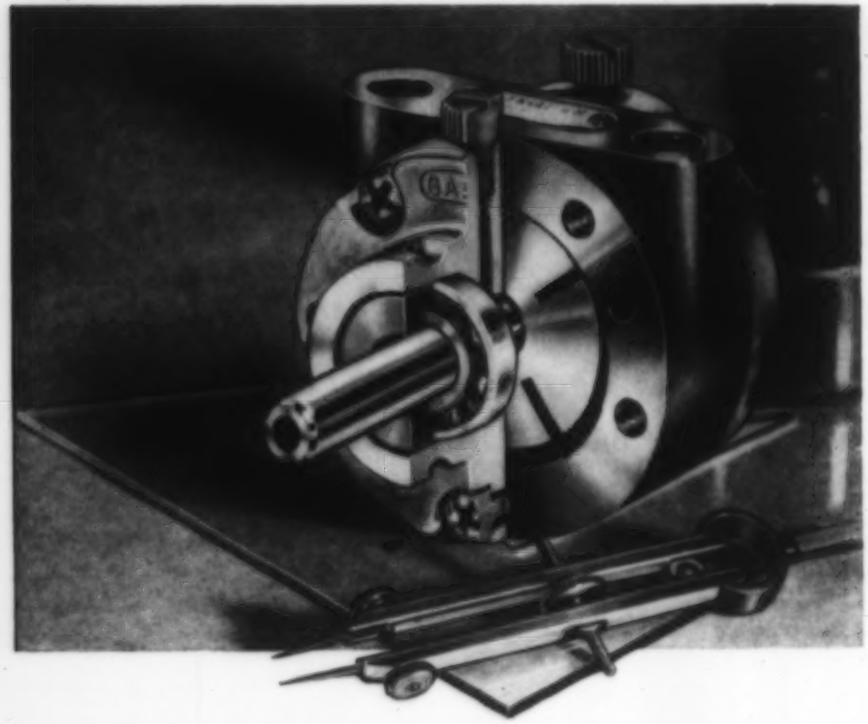

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Air Compressors
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Vacuum Pumps
to 28 in.
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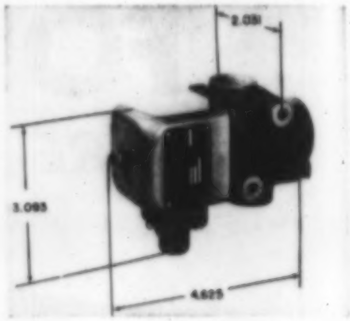


current at 24 v. dc, continuous duty. Made by **Mar Vista Engineering Co., 5420 W. 104th St., Los Angeles 45, Calif.**

For more data circle MD-110, Page 217

Air-Hydraulic Cylinders

Conforming to JIC pneumatic and hydraulic standards, series S cylinders can be operated by either oil or air pressures up to 1000 psi. Positive sealing over entire operating pressure range is assured by U-cup seals on piston. Piston rod seal and rod wiper are mounted in single removable cartridge for ease of service. Bore sizes range from 1½ to 8 in. Seven mounting styles are standard, and practically any stroke length is offered, many from stock. Special mountings, hardened rods and modifications for unusual conditions can be provided. Made by **Hydro-Line Mfg. Co., 5763 Pike Rd., Rockford, Ill.**

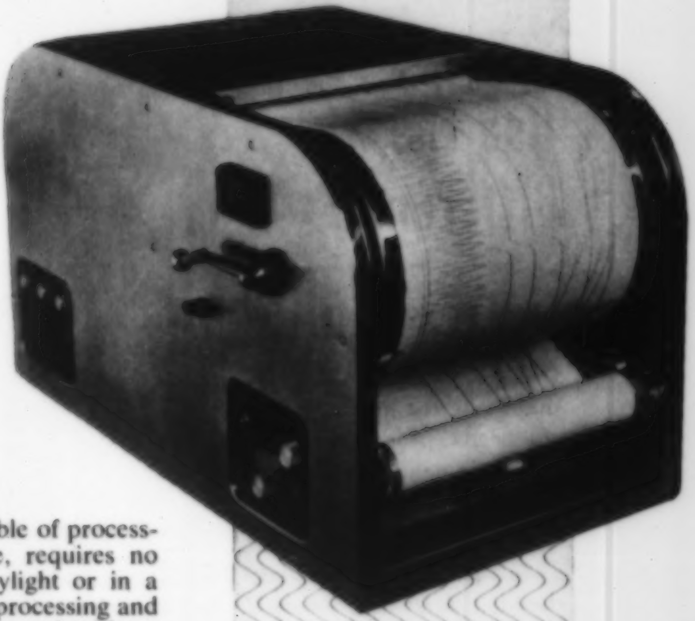
For more data circle MD-111, Page 217

Aluminum Alloy

Aluminum alloy 5357 (K157) for applications requiring an anodized finish similar to polished chrome plate and stainless steel has nominal chemical composition of 0.30 per cent manganese and 1 per cent magnesium. Alloy lends itself favorably to mechanical, chemical and electro-chemical finishing and can be readily welded and brazed, using the proper filler

New, compact photo-record processor

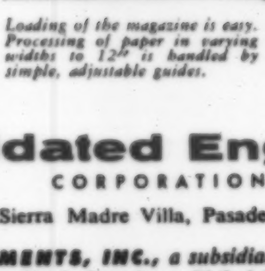
for paper oscillograms and other rolled paper photo-records



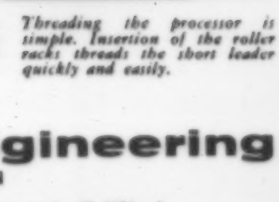
THE TEST ENGINEER'S DILEMMA—how to develop and dry large quantities of test data on rolled sensitized paper—is solved by Consolidated's new Type 23-109 Oscillogram Processor. Built for operation at the actual testing site, this self-contained instrument, capable of processing records as rapidly as 15 feet per minute, requires no external water supply and can be used in daylight or in a normally illuminated room. Simplified loading, processing and unloading techniques permit operation by personnel without previous photo-lab experience. The Type 23-109 processor is compact, portable and fast, requiring only electric power for the paper-transport motor and the drying drum. Where the problem is to save time in processing voluminous test data on photo-record paper, CEC's new oscillogram processor is the practical answer. Write for Bulletin CEC 1537B-X2.

Consolidated

- Reduces time lag between test and interpretation of data.
- Requires no dark room for operation.
- Built for testing-site use without external source of water.
- 250 foot capacity for photo-record paper up to 12" widths.
- Thermostatically controlled solution temperature.
- Automatic squeegeeing for longer solution life.
- Cumulative processed-footage indicator.



Loading of the magazine is easy. Processing of paper in varying widths to 12" is handled by simple, adjustable guides.



Threading the processor is simple. Insertion of the roller racks threads the short leader quickly and easily.

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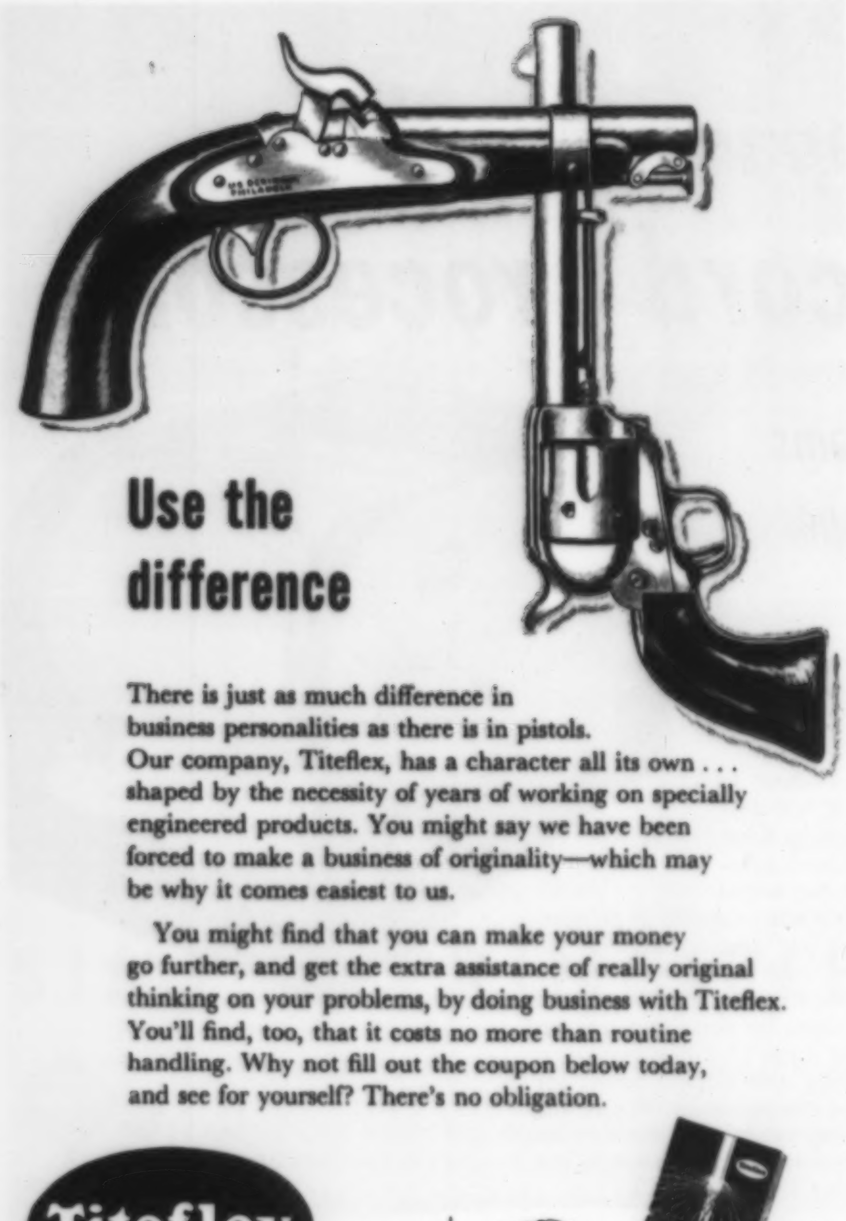

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Left—Deringer Percussion Pistol, 1843   Right—Colt Army Revolver Famous "44", 1872

materials. Tensile strength ranges from 19,000 to 30,000 psi while elongation for respective tempers is 25, 9, 8, 7 and 6 per cent in 2 in. Alloy is available as flat sheet, coil and circles in O, H32, H34, H36 and H38 tempers. Maximum width of flat sheet is 72 in. and gages range from 0.006 to 0.249-in. Coil is offered up to 60 in. wide in gages from 0.006 to 0.125-in. Made by **Kaiser Aluminum & Chemical Corp.**, 1924 Broadway, Oakland 12, Calif.

For more data circle MD-112, Page 217

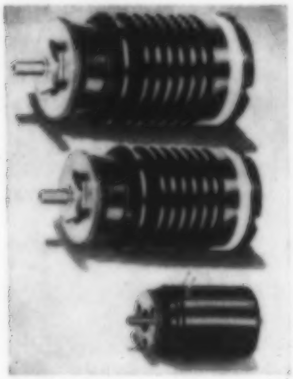
Electrical Wiring Troughs

Conforming fully to JIC specifications, these electrical wiring troughs are completely oil, dust and watertight. Standard sizes include a 16-gage steel, 2½-in. square model offered in lengths of 12, 18, 24 and 36 in. plus a 14-gage, 4-in. square model available in 18, 30, 48 and 72-in. lengths. Cover has neoprene sponge gasket and is fastened to trough by external hinges and clamps. Trough has external mounting feet and is finished in gray hammertone baked enamel. All seams are gas welded. Holes can be punched in trough or cover as desired. Made by **Hoffman Engineering Corp.**, 1064 Tyler St., Anoka, Minn.

For more data circle MD-113, Page 217

Magnetic Clutches

Friction disk type high-speed magnetic clutches are available in three models ranging from 1¼-in. diameter miniature to 2½-in. diameter high torque unit. Torque ratings are available from 20 to 125 oz-in., and, depending on torque requirements, response times range from 0.005 to 0.025-second. Stationary dc coils are available in 12, 24, 48, 80 and 175 v. The two smaller units can be supplied with output braked to ground when de-energized. All



models have concentric input and output shafts on the same end, making possible mounting on gear trains alongside other electrical components such as motors and synchros. Made by Instrument Components Inc., Div. of **Belock Instrument Corp.**, 14-34 112th St., College Point, N. Y.

For more data circle MD-114, Page 217

Repeat-Cycle Timer

Duo-Set timer controls on-off cycling of two independently adjusted load circuits in machine and process control. Timers are available with nine dial ranges from 30 seconds to 4 hours; minimum settings range from ½-second to 4 minutes. Synchronous motor drives elapsed time indicator up scale and down scale to setting pointers. Reversal is smooth, silent and self-synchronizing. Type 5310 timer incorporates

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single-pole, double-throw snap-acting load switch normally set to trip load at zero point on dial. Type 5315 incorporates two load switches normally set to trip both loads at zero point on dial. On both types timer motor reverses at selected limits of elapsed-time-indicator travel. Timer motor is rated at 115 or 230 v; 25, 50 or 60 cycles, 10 w max. Load circuits are rated 15 amp at 115, 230 and 460 v, ac noninductive. Made by **Automatic Temperature Control Co. Inc.,** 5212 Pulaski Ave., Philadelphia 44, Pa.

For more data circle MD-115, Page 217

Hydraulic Cylinder

Heavy-duty Strokontrol ram incorporates an easily adjusted, accurate hydraulic depth stop. Thumb-screw collar on the piston rod can be set at any desired position to stop the retracting stroke at a given point until the collar position is changed. Double-acting cylinder has $3\frac{1}{2}$-in. bore and is available in stroke lengths up to 16 in. Designed for operating pressures up to 1200 psi, it meets SAE and ASAE specifications. Ram utilizes high-strength aluminum alloy castings, a chrome plated piston rod, blocked V-seals, and a smooth honed barrel. Made by **Char-Lynn Co.,** 2843 26th Ave., S., Minneapolis 6, Minn.

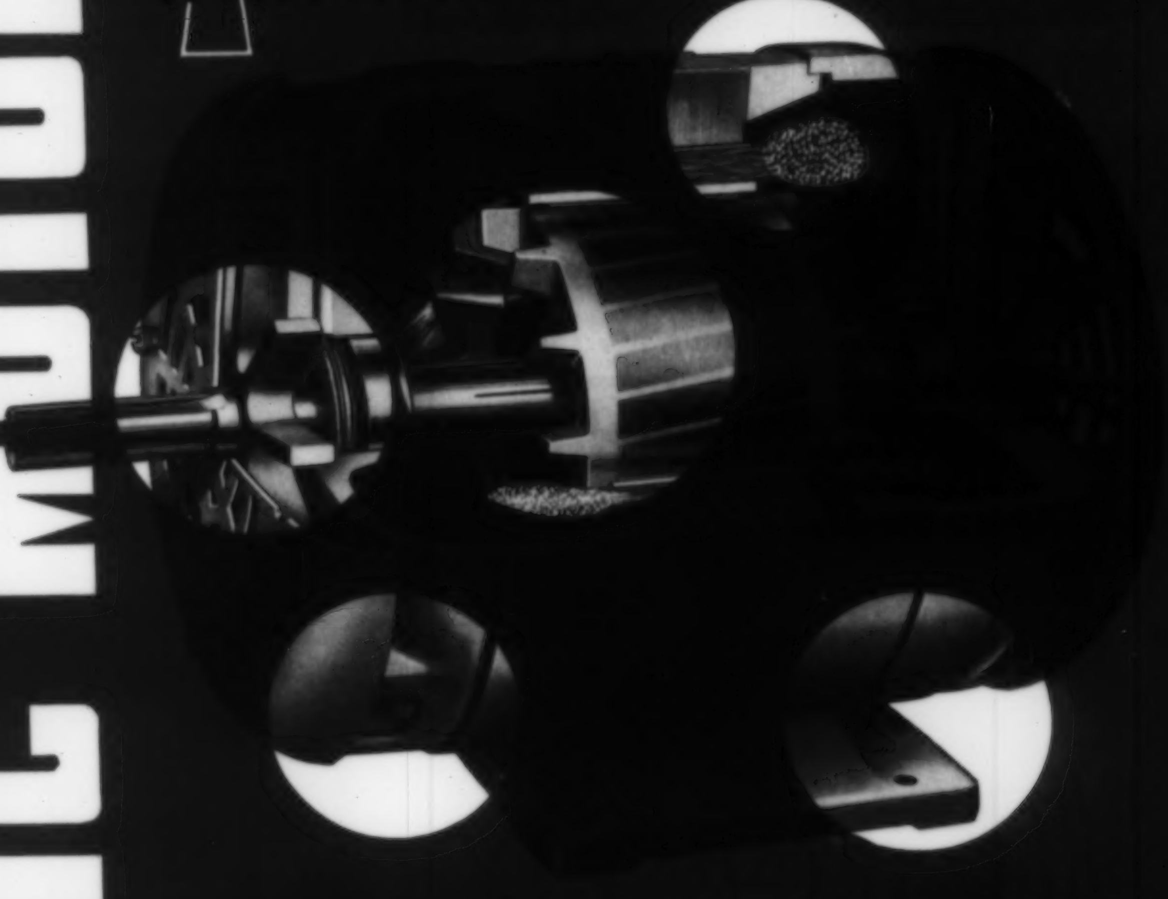
For more data circle MD-116, Page 217

Silicone Foaming Powders

Series of expansible resins for silicone foam structures contain premeasured proportions of resin, filler, blowing agent and catalyst. Mixes melt, foam and cure by themselves when heated, requiring

BALDOR MOTORS

look....here's our secret



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[illegible] Baldor Motors Available—Built to [illegible] NEMA Standards

BALDOR ELECTRIC COMPANY

Baldor Motors Are Available in Polyphase • Squirrel Cage
Induction and Single Phase • Capacitor Start • Induction Run Types

[illegible] DUNCAN AVENUE • ST. LOUIS 10, MISSOURI

Norgren

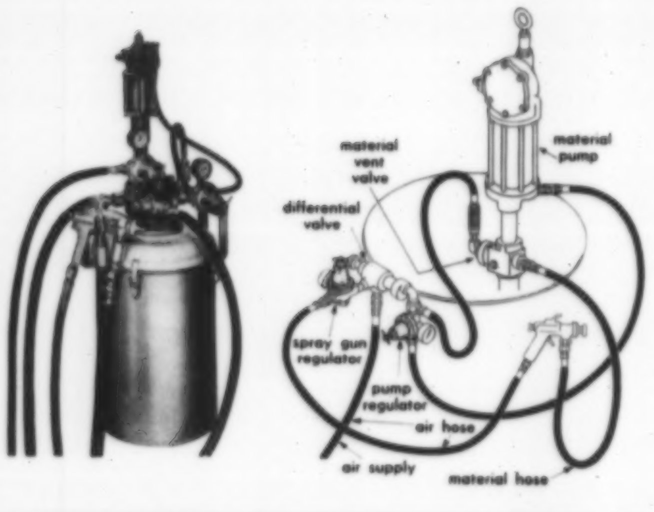
PRESSURE REGULATORS
selected by

LINCOLN ENGINEERING CO.

as standard equipment on
MATERIAL DISPENSING PUMPS

Their competitive tests proved that Norgren Regulators...

- **had a larger flow capacity at pressures up to 80 psi**
- **gave better pressure control**
- **resulted in cost savings because ½" Norgren Regulators replaced ¾" units.**



The Lincoln Material Dispensing Pumps are air-powered units incorporating a 4" air motor and a balanced pump tube design which results in material flow on both upward and downward strokes. The problem was to obtain pressure regulators which would handle sufficient air flow for operation of pump, pressure flow equalizer and spray.

Extensive competitive tests resulted in the selection of Norgren Regulators which resulted in better performance and a saving in equipment costs.

C. A. Norgren CO.
3442 So. Elati, Englewood, Colo.

FOR COMPLETE DETAILS
WRITE FOR NORGREN
BLUEPRINT NO. 119

Valves • Filters • Regulators • Lubricators • Hose Assemblies

no further mixing or processing. Identified as R-7001, R-7002 and R-7003, the three mixes are nontoxic, easily handled and unaffected by humidity or atmospheric pressure. They can be cast into sheets or blocks, made up as sandwich structures or foamed in place. Only negligible pressure is exerted during expansion. Density can be controlled from 8 to 18 lb per cubic foot by varying expansion temperatures. Three mixes produce a graduated range of mechanical strengths at elevated temperatures. All remain stable up to 700 F. Made by **Dow Corning Corp.**, Midland, Mich.

For more data circle MD-117, Page 217

Variable-Speed Transmissions

Several new models of Zero-Max infinitely variable-speed transmissions include such variations as double output shafts, both input and output shafts on the same side of the unit, and shafts opposite from the standard unit (type SO, illustrated). Special speed control arms in various lengths are available for all models, as well as special control arrangements such as a spring-return type. Made by **Revco Inc.**, 2 E. Franklin Ave., Minneapolis 4, Minn.

For more data circle MD-118, Page 217

Silicone Rubber

Cohrlastic HT Molding 400 and HT Extrusion 600 silicone rubbers possess mechanical properties which compare favorably with those of synthetic rubbers. Tensile

Norgren

MICRO-FOG LUBRICATION

can help you...

- **reduce machine wear**
- **increase bearing life**

Here's what Micro-Fog did for

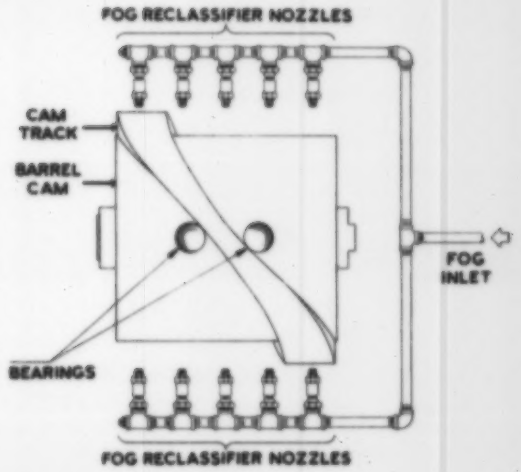
UNIVERSAL MATCH CORP.

on 6 large printing presses

- **eliminated flaking and galling of cam track**
- **eliminated heating and excessive wearing of bearings**
- **eliminated constant squealing of barrel cam**
- **eliminated daily manual lubrication**

Oscillating movement of table on the printing press is achieved by a 16" dia. barrel cam rotating at 150 rpm. A Norgren Lubro-Control Unit (Filter, Regulator, Lubricator) was installed to lubricate the cam, cam track and follower roll bearings. It solved the lubrication problem so successfully that similar units were installed on the other five presses.

Two ¼" pipe lines, 18" long, carry Micro-Fog to 5 reclassifiers on each side of barrel cam. 10 psi air pressure used. Solenoid valve coordinates lubricant flow with press operation.



FOR COMPLETE DETAILS
WRITE FOR
NORGREN BLUEPRINT No. 118

C. A. Norgren CO.
3442 So. Elati, Englewood, Colo.

VALVES — FILTERS — REGULATORS — LUBRICATORS — HOSE ASSEMBLIES

strengths range from 1000 to 2000 psi; tear strengths, from 200 to 300 lb per in. Material remains stable in temperature range from −65 to 400 F, is resistant to weathering and ozone and has high dielectric strength. The HT compounds are available in the form of sheets and molded parts. Made by **Connecticut Hard Rubber Co.,** 407 East St., New Haven, Conn.

For more data circle MD-119, Page 217

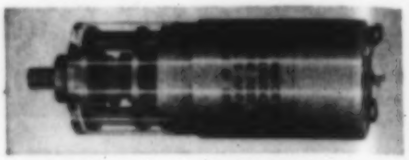
Mechanical Counter

Rated for production-control applications at up to 3000 counts per minute, Rayconter model 550 cumulative counter registers counts up to 999,999. Registration is by four pointers on four concentric scales reading from the center outward. Low-inertia mechanism minimizes error from carry-over. Instrument also has a pawl and pinion drive with an interlocking device designed to prevent multiple counts. Housed in an anodized aluminum case, the counter has a full-sized bezel and convex plastic front window. It is designed for either flush-panel or projecting mounting. Dimensions are $3\frac{1}{2}$ in. diameter x 2 in. deep. Made by **Raycon Corp.,** 841 Willow St., Redwood City, Calif.

For more data circle MD-120, Page 217

Miniature DC Motor

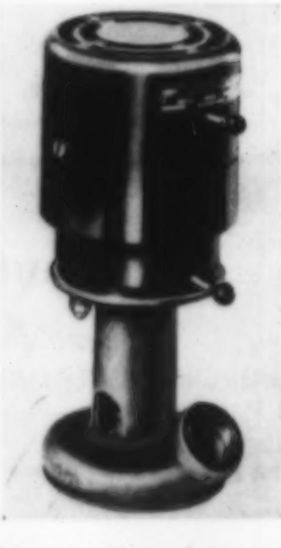
Designed for timing equipment and other applications requiring constant speed under continuous use, model 1300-1 permanent-magnet gearmotor measures $1\frac{1}{8}$ in. OD and less than 3 in. long. It weighs $4\frac{1}{2}$ oz. Motor can be designed for any input voltage from 6 to 30 v dc and has an output of 6 w maximum for continuous duty or 12 w maximum for intermittent duty. Motor output speed can be from $\frac{1}{2}$ to 9000 rpm, depending on gearing. Motor has aluminum alloy case with molded plastic brush housing. Ball bearings are sealed and permanently lubricated. Motor can be supplied with leads or feed-through terminals, or with a governor which provides a control range of ±1 per cent for a constant load over ±10 per cent voltage range. Made by **El Ray Motor Co.,** North Hollywood, Calif.



For more data circle MD-121, Page 217

Small Pump

Series H-3000 Superflo pump delivers 10 gpm of water at a 3-ft head. Designed for pumping water and other liquids of light viscosity, it operates smoothly and quietly and delivers a steady flow without cavitation. Operating with low liquid level, pump has extensive range between minimum and maximum liquid levels. Bronze and stainless steel are used in fabrication of the pump, and its shaded pole motor is fully enclosed and fan-cooled. Lubrica-



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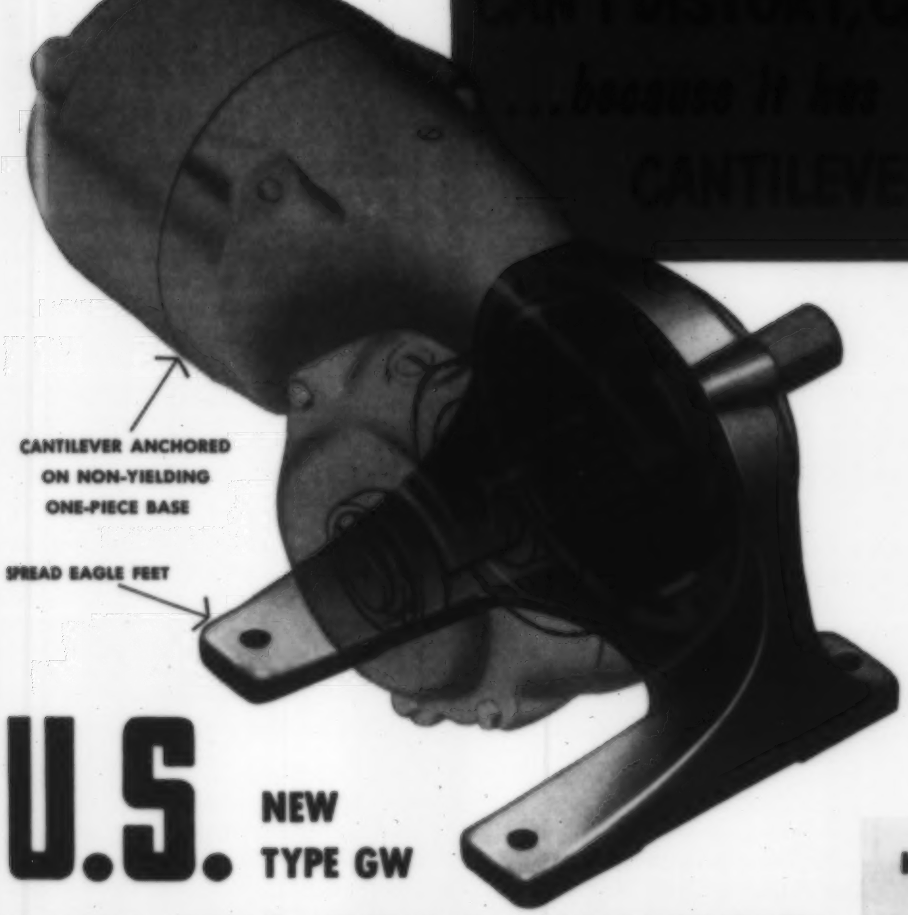
600 MCM — 6
TERMINAL BLOCKS
LOK-A-BLOK

CAN'T DISTORT, CAN'T MISALIGN ...because it has CANTILEVER DESIGN!



RIGHT-ANGLE

WORM-GEAR

SOLID CAST UNIBASE

PYRAMIDAL SUPPORT

CLOSE-HITCH

SEALED PROTECTION

U.S. NEW TYPE GW SYNCROGEAR MOTOR

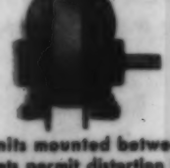
Mounting stresses absorbed.
Gear and motor distortion-free.

Permanently accurate gear and bearing alignment are vital in any right-angle, worm-gear motor. In the amazing new Type GW Syncrogear motor the *cantilever* principle is employed. Why? —To prevent stress of motor and gear mounting. A solid-cast Unibase pyramidally supports the entire load. Type GW is extremely compact. Gear is sealed in dustproof case. Speeds, 20 to 155 r.p.m. Gear ratios up to 87:1. Horsepower, ¼ to 2.

RIGID
SMOOTH
QUIET
U.S. SYNCROGEAR MOTOR

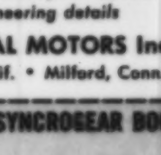
HOW U. S. CANTILEVER DESIGN INSURES ALIGNMENT

U. S. MOTOR DESIGN



Motor and gearing mounted on single base. Cantilever position of motor is independent of external mounting stresses. Uneven floor mounting can't set up stress.

ORDINARY DESIGN



Gear and motor units mounted between two separate brackets permit distortion by bolting to irregular mounting surfaces.

New multi-colored descriptive booklet gives full engineering details

U. S. ELECTRICAL MOTORS Inc.
Los Angeles 54, Calif. • Milford, Conn.

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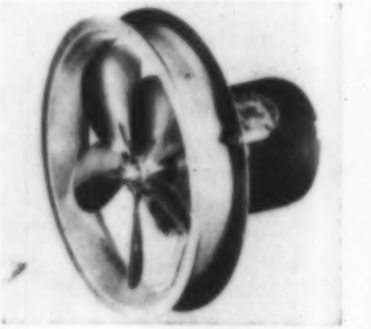
tion cups are easily accessible. Made by **Graymills Corp.**, 3705 N. Lincoln Ave., Chicago 13, Ill.

For more data circle MD-122, Page 217

Blower

Built to conform to military specifications, model F7-1 blower has 960 cfm air volume, based on NEMA code. Equipped with a 7-in., five-bladed fan, it operates at a speed of 3400 rpm. Under NEMA code, it will move 525 cfm free air. Motor operates on 115v, 60 cycle, single-phase ac. Motor case is totally enclosed. Made by **Mission-Western Engineers Inc.**, 132 W. Colorado St., Pasadena 1, Calif.



For more data circle MD-123, Page 217

Modulator-Amplifier

Small Spelco-Serv modulator-amplifier has fractional-watt input and 100-watt output. It accepts ac, dc and phase-shift error or control signals as low as 50 mv, senses their phase or direction and supplies output power at a gain of 300 to 1000 absolute value. Unit is on

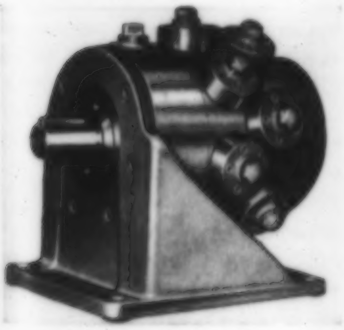
SPELCO-SERV
MOD-II TYPE P-1
SPELCO
LOS ANGELES, CALIF.

a power supply with a frequency range of 200 to 800 cycles per second; 60-cycle units can be supplied. Loads may be resistive or inductive. Unit withstands high g loads and operates over temperature range of −90 to 300 F. Models are available completely hermetically sealed or with externally mounted tubes. Many circuit combinations are possible. Made by **Standard Plastics and Electronics Co.,** 1540 S. Robertson Blvd., Los Angeles 35, Calif.

For more data circle MD-124, Page 217

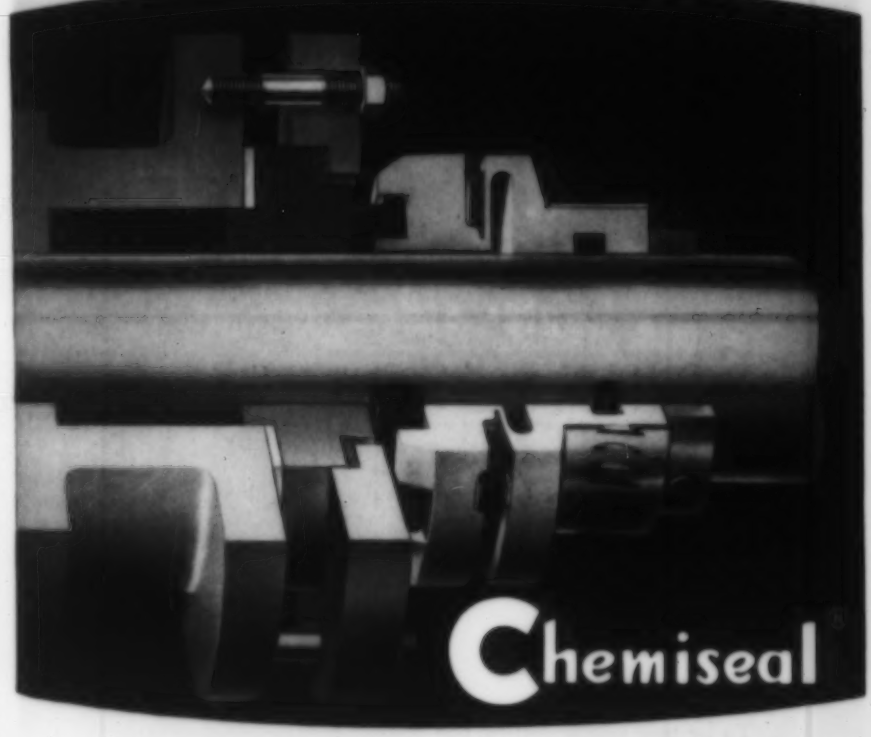
Radial Hydraulic Pumps

Heavy-duty fixed displacement radial hydraulic pumps meet high horsepower and high pressure requirements. Model C-5 delivers 5 gpm at a maximum pressure of 10,000 psi and requires 38 hp input at maximum pressure. Model C-11 delivers 10 gpm at a maximum pressure of 5000 psi and requires 35 hp at maximum pressure. High pressure is generated by means of patented hollow piston design. Each piston assembly is completely surrounded by high-pressure lubricant, so that it floats in a hydrostatic film of oil during its power stroke. Bearing assembly delivers power through special heptagonal bearing races, minimizing friction and providing maximum contact area at points of piston actuation. Fluid timed ball check valves provide quiet and efficient operation at all pressures. Made by **Simplex Engineering Co.,** Newark Rd., Zanesville, O.



For more data circle MD-125, Page 217

Here is the Shaft SEAL you have been wishing for



Chemically Impervious TEFLON Balanced Bellows Design

Three years of actual field tests have proven that Chemiseal external mechanical seals last longer and give unsurpassed performance under a wide variety of chemical service conditions—handling acids, alcohols, alkalies, hydrocarbons, and related chemical compounds including abrasive slurries and tarry material (with provisions for flushing).

Combining the Bellows design, which provides pressure balance so essential for long leak free service, with duPont TEFLON the wonder plastic for immunity to corrosion and contamination—United States Gasket engineers have produced a mechanical seal which makes "sealing" simple and economical for the process industries.

FEATURES

- **CHEMICALLY IMPERVIOUS** TEFLON Bellows section. A selection of seal face materials dependent upon medium and service requirements.
- **SEAL ROTATES WITH SHAFT** Only bearing surface is between precision ground rotating and stationary seal faces. Low friction load on shaft. Lower power cost. Drop tight service.
- **NO SCORING OF SHAFTS** and Chemiseals work satisfactorily on shafts previously scored by other seals or packing.
- **LIFE EXPECTANCY** many times that of other seals or packing.
- **PRESSURES** at the seal up to 100 psi at 75°C or 75 psi at 100°C.
- **SIZES** from ½" to 2½". Other sizes for special applications.
- **MAXIMUM LENGTH,** all seals 2¾"

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ENGINEERING DEPARTMENT EQUIPMENT

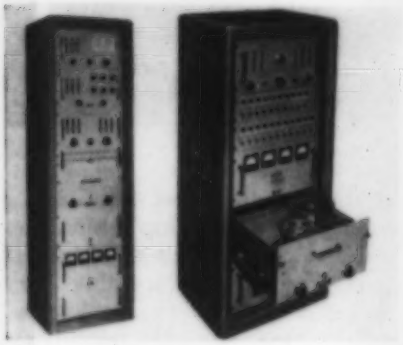
Automatic Drawing Pen

Rule-O-Matic ruling pen contains an ink cartridge holding the equivalent of 55,000 in. of ruled lines. Pressing the cap of the pen activates a concealed feed tube which releases the exact amount of ink needed to fill the nib. Nibs are rustproof, precision honed stainless steel. Government-approved India ink is prepared by Artone Color Corp. Pen is made by **Rule-O-Matic Corp.,** 38 E. 57th St., New York 22, N. Y.

For more data circle MD-126, Page 217

Electronic Brain

Vic-Dar data accumulation and reduction system tests variables such as speed, position, motion, pressure, strain and heat and translates them into digitized values which can be used for analysis. It provides the means of continuous split-second measurement of the variables being tested. By means of converters, the variables—expressed as analog output voltages — are measured and electronically converted to proportional unitary counts. Readings are taken simultaneously and at rates from one to ten times per second. System comprises two units. The data recorder, in addition to housing the 20 transducers, includes a magnetic tape recorder for storage of test results. It also provides for a voice explanation of the tests as conducted. The digital translator reduces the data for listing, or for card punching or further mathematical calculations. Made by **Victor Adding Machine Co.,** 3900 N. Rockwell St., Chicago 18, Ill.



For more data circle MD-127, Page 217

Cross-Section Paper

Cross-section paper with nonreproducing lines is now available with 4, 5, 6, 8, 10, 12, 16 and 20 squares to the inch, as well as with millimeter and isometric divisions. Paper is either 100 per cent rag treated vellum or 100 per cent rag natural bond tracing stock, suitable for blueprint, black and white or Ozalid reproduction. Paper is made 30 in. wide in rolls 20 and 50 yd long and in sheets up to 24 x 36 in. Made by **Ogilvie Press Inc.,** 691 Fulton St., Brooklyn 17, N. Y.

For more data circle MD-128, Page 217

Data Tables

No. 101 Datable is an engineering data table with a self-adhesive back. Measuring 2⅝ x 17 in., it can be applied to a fluorescent lamp shade, as well as other surfaces. Three tables provide decimal equivalents to four places; twist drill sizes, specified by number and letter; and six standard

RR
TEKTRONIX
ROTH RUBBER COMPANY

Roth Rubber Solves Rubber Problem for West Coast Manufacturer!

A viewing hood for an oscilloscope seems like a simple problem for the rubber technologist, yet it is significant that Tektronix, Inc., of Portland, had Roth Rubber, in Chicago, provide the solution. The viewing hood must not crack or buckle, has to adjust to any face and must exactly fit the Tektronix scope. Roth engineers solved this problem—they can solve *yours*.

Engineers and Rubber Buyers!

Write for your free Roth Rubber Sampler. This unusual kit contains actual rubber samples with hardness from 5 to 100 Durometer . . . gives ASTM specs and lists uses for each sample. Sorry, but offer must be limited to engineers and rubber buyers only. Please ask for Roth Rubber Sampler No. MD4.

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LIFT

the efficiency of your hydraulic unit with Roper dependable Pumps. Get optimum performance from the pumps that feature just two moving parts — equal size gears operating in a sturdy case with proper clearance for superior service and long-life. The models shown are representative of standard Roper pumps suitable for most applications.

Specify
ROPER
Rotary Pumps
FOR YOUR
HYDRAULIC
APPLICATIONS

LOWER

maintenance costs with a Roper. For instance, a pump like the Series H with pressures to 1000 P.S.I., sizes 10 to 75 G.P.M. is ideally suited for hydraulic mechanisms and for other applications requiring high pressures. Spur gears run in axial hydraulic balance . . . bearings and bronze wear plates reduce friction under heavy loads. Available with packed box or mechanical seal.

PUSH

the unit in your hydraulic circuit with the correct size Roper for the particular job. In many cases the Series K will do, for it is rated from pressures to 150 P.S.I., capacities ¾ to 30 G.P.M. This model is compact, sturdy . . . is self-lubricated by liquid pumped . . . handles total suction lifts up to 25 feet. Comes with packed box or mechanical seal . . . with or without relief valve.

PULL

favorable comment on a wise choice when you install a Roper as original equipment. Among the dependable Ropers is the Series F Pump — pressures to 300 P.S.I., sizes 1 to 300 G.P.M. It features four-part design with 8 optional piping arrangements . . . supplied in standard or stainless steel fitted models. With packed box or mechanical seal, with or without relief valve.

ROPER
Rotary Pumps

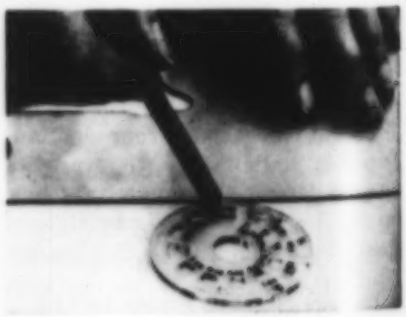
GEO. D. ROPER CORPORATION
241 Blackhawk Park Ave., Rockford, Illinois

gages for wire, sheet metal and/or tubing in aluminum, brass, copper, Monel, nickel, phosphor bronze and steel, including stainless and spring. The table is resistant to heat and humidity and may be cleaned with a damp cloth. Made by **Timber-Top Products,** P. O. Box 14, Sherman, Conn.

For more data circle MD-129, Page 217

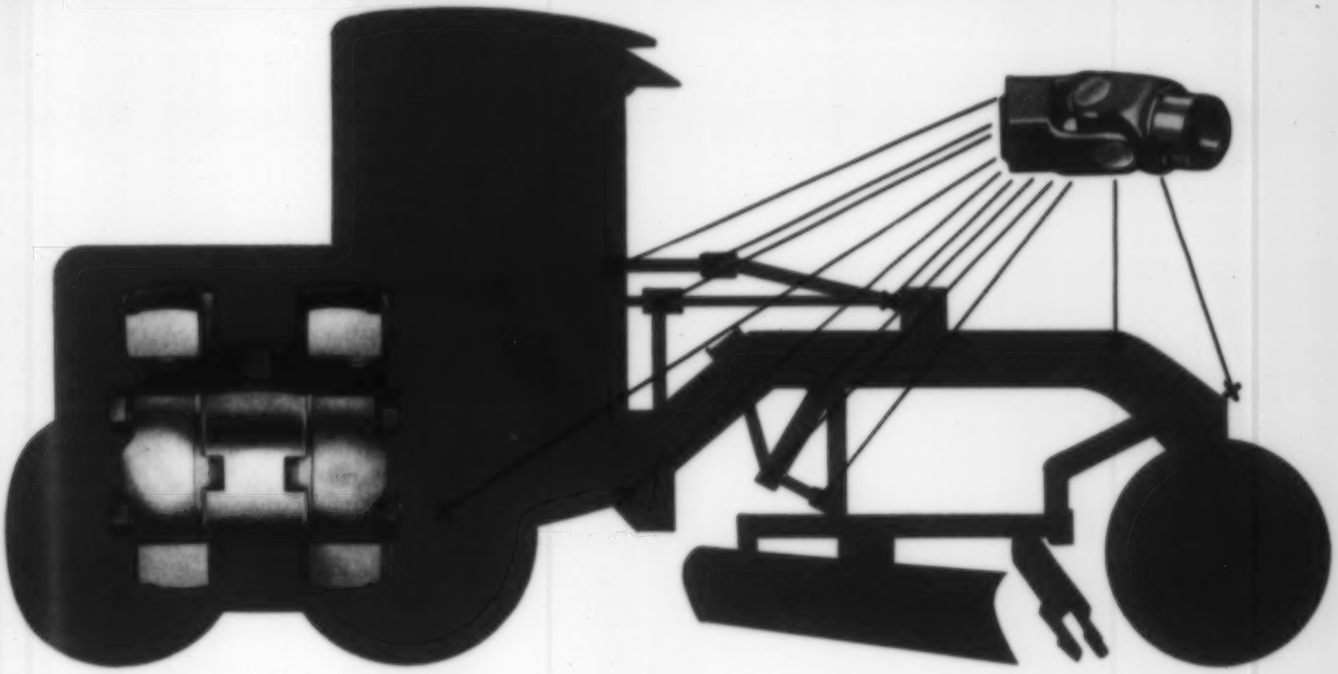
Line Spacer

Seventeen slots in the Linemaster drafting tool are used to produce parallel lines 1/64-in. and 1/32 to ½-in. from a base line in steps of 1/32-in. Made of heavy plastic, device makes accurately spaced lines for layout and engineering drawing, lettering and cross-hatching. Pencil or scriber point is placed in one of the slots, all of which are precisely located in relation to circumference of disk to within 0.002-in. of dimension marked on it. In use, the 2¼-in. disk is placed against a straightedge or curve, positioning itself automatically as the line is drawn. Made by **Dri-Flo,** 642 E. Ten Mile Rd., Hazel Park, Mich.



For more data circle MD-130, Page 217

RELIABLE



Whether for close-coupled main drive lines or for exposed steering and adjustment drives, designers with JOINT problems have learned to rely on MECHANICS. Where joints must run all day at high angles — where there are severe shock loads — where wide angles and long slip are common — and where dirt and/or moisture constantly are present — MECHANICS Roller Bearing UNIVERSAL JOINTS are the accepted solution. *Lubrication is so tightly sealed in that dirt and moisture cannot enter.* If you have a "tough" joint problem, make use of MECHANICS field engineers' wide experience.

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Users report that

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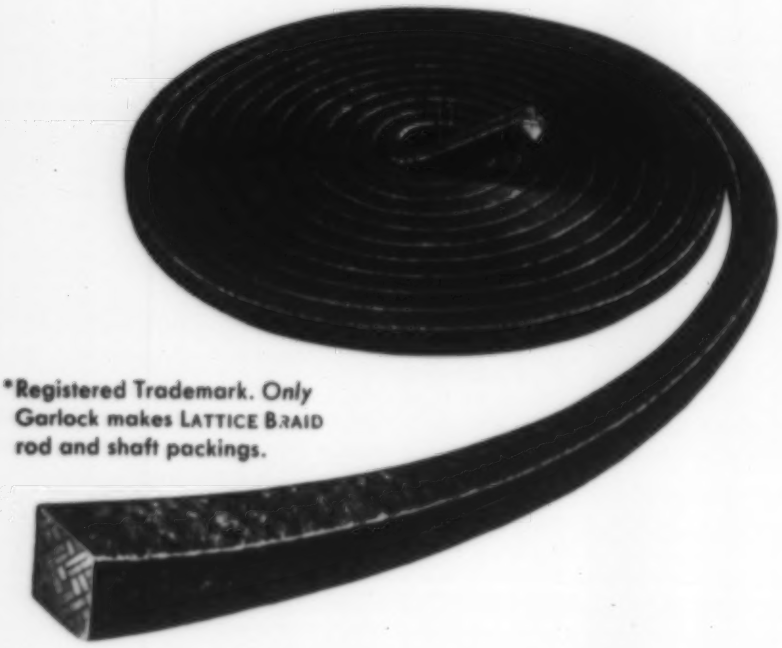
ROD AND SHAFT PACKING

has these 5 advantages



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1. Requires *less* gland pressure
2. Causes *less* sleeve and shaft wear
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Put Garlock LATTICE BRAID Packing to work for your company. All the braided strands of this unique packing are lattice linked together into one structural unit. The strands hold together even when the packing is worn far beyond the limits of wear of ordinary braided packings.

LATTICE BRAID is made from flax, cotton, asbestos, wire-inserted asbestos, Teflon, and asbestos with Teflon impregnation—for various types of services.

Get all the facts about LATTICE BRAID *Packings. Contact your Garlock representative or write for new folder AD-131.*

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GARLOCK LATTICE BRAID PACKING

THE ENGINEER'S Library

Recent Books

High-Temperature Alloys. *By Claude L. Clark, metallurgical engineer, special steel developments, The Timken Roller Bearing Co.; 397 pages, 6 by 9 inches, clothbound; published by Pitman Publishing Corp., New York; available from* MACHINE DESIGN, $7.50 *postpaid.*

Engineering aspects of high-temperature alloys are stressed in this book for students and designers. It is an attempt to summarize the present status of knowledge about the behavior of alloys at elevated temperatures, with emphasis on ferrous rather than nonferrous alloys.

In 21 chapters this book discusses temperature trends in industry, mechanism of plastic deformation, qualifications for high-temperature service, laboratory methods for evaluating alloys, short-time strength tests, creep strength, creep and stress-rupture tests, load-carrying ability, influence of alloying elements, alloy steels, super-high-temperature alloys, service failures, physical constants, properties, selection for specific applications, specifications, codes and related activities. Amply illustrated, the book also contains many useful charts and tables.

•

Dynamics in Machines. *By F. R. Erskine Crossley, assistant professor of mechanical engineering, Yale University; 469 pages, 6 by 9 inches, clothbound; published by The Ronald Press Co., New York; available from* MACHINE DESIGN, $7.00 *postpaid.*

This textbook is intended as a sequel to studies of statics, dynamics and strength of materials. It provides an opportunity to apply fundamental skills to analysis of dynamic problems in machine design.

In ten chapters the book covers

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5/16" high

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-Cost, Explosion-Proof SKINNER Solenoid Valve
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For hazardous locations, specify the Skinner Safety X5 Series Valve. It's Underwriter Approved for Class I, Group D, and Class II, Groups F and G. And no other explosion-proof valve has the simplicity and flexibility of the X5 design!

Skinner Safety X5 Series valves are skillfully engineered to give trouble-free operation through [redacted] They are direct acting, spring loaded, *leakproof* . . . and give positive performance in any position.

Valves of this series have stainless steel internal parts and are offered in five basic types: two- and three-way normally open; normally closed; and directional control. They are available with a broad selection of electrical outlets, port locations and sizes, flow adjustments and coil types.

Media — Air, gases, vacuum, oil, water and many semi-corrosive media.

Pressure Rating — 0-1000 p.s.i.

Construction — Leakproof sealing, bubble-tight shut-off at all ports; packless, frictionless construction; precision-machined stainless steel internal parts; electronically-controlled, pressure-tested welds.

Simplified Servicing — can be disassembled and repaired without removal from the line.

Specifications — *Duty Cycle* — continuous or intermittent.
Orifice Diameters — 3/64" to 1/4".
Pipe Size — 1/8" or 1/4" NPT.
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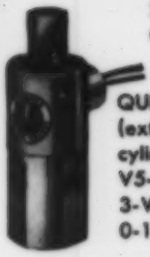

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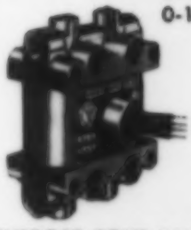

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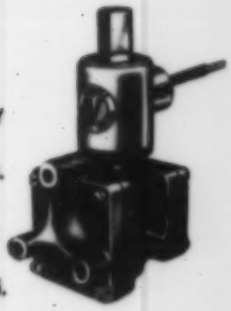

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introductory kinetics, equations of motion, simple harmonic motion, balance of rotors and critical speeds, damped and forced vibrations, three-dimensional rotation, static and dynamic forces in machines, flywheels and engine balancing, flexible machine members in motion and governors. The book is profusely and clearly illustrated, and appropriate examples and problems appear in all chapters.

•

Strength and Resistance of Metals. *By John M. Lessells, president, Lessells and Associates Inc., and associate professor of mechanical engineering, emertius, Massachusetts Institute of Technology; 464 pages, 6 by 9 inches, clothbound; published by John Wiley & Sons Inc., New York; available from* MACHINE DESIGN, *$10.00 postpaid.*

The aim of this volume is to provide students and design engineers with information on the behavior of metals under stress. Most of the discussion centers around the characteristics of steel; however, mention is made of nonferrous alloys and cast iron in those particular instances where their behavior differs from that of steel.

In 11 chapters, subjects covered include tensile testing, elastic-stage modification, tensile properties at elevated temperatures, hardness, impact, normal conditions and controlling factors of fatigue, fracture of metals, strain hysteresis, mechanical wear, and theories of strength and working stress. Problems and tables of logarithms, antilogarithms and trigonometric functions are appended.

•

Design Nomographs. *By James J. Kerley Jr., structural engineer; 19 pages, 8½ by 11 inches, ringbound, paper covered; available from Golibart Press, 6203 Forest Road, Cheverly, Md., $1.00 per copy postpaid.*

This booklet contains nomographs useful in solving mechanical design problems. Charts re-

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Contractors demand equipment with a Fuller torque converter coupling

Two workhorses in construction equipped with Fuller Torque Converter Couplings: Hough Model HM PAYLOADER (above), Pettibone Mulliken SPEEDALL, Front End Loader (right).

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•

Fiberglas Reinforced Plastics. *By Ralph H. Sonneborn, Owens-Corning Fiberglas Corp.; Albert G. H. Dietz, Massachusetts Institute of Technology; and Alton S. Heyser, Reed Research Inc., Washington, D. C.; 252 pages, 5½ by 8½ inches, clothbound; published by Reinhold Publishing Corp., New York; available from* MACHINE DESIGN, *$4.50 postpaid.*

This book offers a thorough treatment of reinforced plastics. It covers resins, glass reinforcements, molding techniques, inspection, testing, properties and design considerations. Other topics treated in the ten chapters include nature and uses, composition, manufacturing processes, machining, joining, painting, repair, applications, design theory, and structural design. Appendixes include a glossary of terms as applied to fiberglas reinforced plastics.

New Standards

Graphic Symbols for Electrical Diagrams. *ASA Y32.2-1954; 60 pages, 8½ by 11 inches, paperbound; available from American Standards Association, 70 East 45th St., New York 17, N. Y., $1.25 per copy.*

Providing a list of graphical symbols for use on electrical diagrams, this standard is a complete revision and co-ordination of five American Standards for graphical symbols. Publication is for use of designers to show the interconnections and functioning of electrical circuits. Symbols are arranged alphabetically and indexed.

Association Publications

Testing of Stainless Steel Weldments—*Bulletin No. 18. By Helmut Thielsch, metallurgical engineer, Grinnell Co., Providence, R. I.; 26 pages, 8¼ by 11¼ inches, paperbound; available from American Welding Society, 33 West 39th St., New York 18, N. Y., $1.00 per copy.*

This bulletin of the Welding Research Council series contains a review of published and unpublished information on mechanical tests, procedure-qualification tests, fluorescent and dye-penetrant inspection, radiographic and ultrasonic inspection, sectioning of welded structures, magnetic inspection, corrosion testing, metallographic tests, ferrite, carbide and sigma-phase determination and crack-sensitivity tests of stainless steel weldments.

Manufacturers' Publications

Aluminum Extrusions. *36 pages, 8½ by 11 inches, paperbound; available from Harvey Aluminum, 19200 S. Western Ave., Torrance, Calif., on company letterhead request; additional copies $1.50 each.*

Purpose of this publication is to describe uses to which aluminum extrusions can be applied in new design and to aid in improving existing designs. Material covered includes current applications, design advantages, fabricating, finishes, alloys and tempers, resistance to corrosion, cost considerations, mechanical and physical properties, and terminology.

Government Publications

NACA Technical Series. *Each publication is 8 by 10½ inches, paperbound, side-stapled; copies available from National Advisory Committee for Aeronautics, 1924 F St., N.W., Washington 25, D. C.*

The following Technical Notes are available:

3232. **An Analysis of the Stability and Ultimate Bending Strength of Multiweb Beams with Formed-Channel Webs**—28 pages.

3257. **Effects of Chemically Active Additives on Boundary Lubrication of Steel by Silicones**—24 pages.

3259. **Investigation of Nickel-Aluminum Alloys Containing from 14 to 34 Percent Aluminum**—42 pages.

3291. **Experimental Investigation of Notch-Size Effects on Rotating-Beam Fatigue Behavior of 75S-T6 Aluminum Alloy**—47 pages.

3310. **Investigation of Static Strength and Creep Behavior of an Aluminum-Alloy Multiweb Box Beam at Elevated Temperatures**—2 pages.

Stress Relief

SOMETIMES somebody says something that we all know —and forget. Here's one that's worth recalling to mind. It appeared as the guest editorial in an engineering department news sheet at International Harvester.

Teamwork

Teamwork is a word that has come to occupy a very important place in America. It has come to indicate that quality of a group that explains its ability to overcome superior numbers, or conditions—to win against odds.

Athletes are schooled in the art of teamwork, with each member depending on and expecting the other to do his share. While it is true that some players shine more brightly than others, none ignores the fact that the key block makes the touchdown run possible, that a successful pass requires the whole team, not just the passer.

This co-ordinated combination of skills and talents is also a factor in the business world. All other things being reasonably equal, it will produce a sense of individual security, and needless to say, a higher output.

In a broad sense, the division of labor upon which our civilization rests is a matter of teamwork. In earliest cave-man days, man depended upon his own skills and abilities to survive. As civilization progressed, man divided into groups of farmers, traders, sailors, etc. With the coming of the so-called industrial revolution and the production methods of recent times, man finds himself dependent upon a multitude of others for simple existence. A man living by himself, without the benefit of any of the products or services of mankind, is rare indeed.

In business, the need for teamwork is more important to man than in any other aspect of life,

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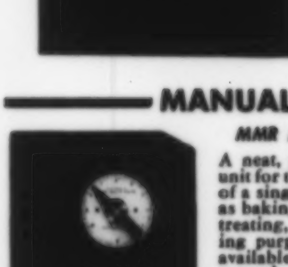

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for the products and services that are supplied are the life blood of man. Although there are many factors involved in the success of a business, the overriding factor is the efficiency of the human beings using these factors. A good product can be poorly manufactured. A well manufactured product may never get to the consumer through poor distribution, sales, etc. An entire well-run organization may suffer because of a poorly designed product. There are thousands of variations to these factors in a complex business, but the *X* value is always the human element. A tool is only as good as the human being using it. A file, typewriter, automatic gear shaper, or electronic brain is no better than the humans who made and those who run it. It needs both. And the results of any of the tools are no better than the finished unit to which it is assembled. An individual may be more or less skillful and efficient, but the important thing is how the complete group works together to provide the unit for use.

In the specific field of product design the least recognized factor is that of teamwork. Through a number of misconceived ideas and misinterpreted occurrences, people have come to assign the results of design endeavors to one man. A given design is said to be so-and-so's. Certain people refer to "my machine" or "my design." Except in extreme cases where only one man is involved in the whole process of conception, development, building, testing, etc., the identification of a design comes about as a result of many factors. A well-conceived idea, good design, development, and prosecution by all are involved. If any one of the parties involved does a poor job, completion is delayed and often made impossible.

Unfortunately for good design, the type of person usually engaged in design work is the prima donna or star type. And to complicate the problem further, complete designs require many more people who must learn to work together. Specialization has resulted in complete lack of knowledge of the other factors neces-

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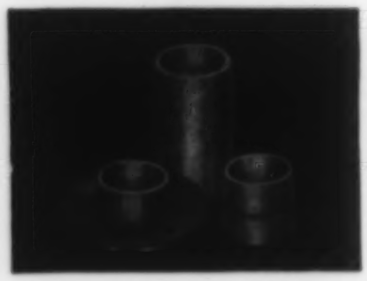

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sary, and the overemphasis of the individual contribution. This means that the combining of a group of specialists to accomplish a complex operation must first overcome the heterogeneous qualities of the group before any real combining of the talents is accomplished.

Put simply, no group of persons will accomplish any worthwhile task until each member submerges his own desire to appear most important and contributes his share to the overall task. The glory or credit grabbers must change their ways or else resign themselves to the fact that they will never be part of a successful group.

Another misconception in design work is the emphasis on the so called "genius." A genius, like an electronic brain, is no better than the people surrounding him. As a matter of fact, assignment of "genius" to any one, except by his own coworkers, results in immediately unfavorable reaction of his coworkers.

A group of "average" design people with the magic element of teamwork can do better and more design work than the highest paid group of specialists. The result of teamwork is greater than the sum of the individual talents. The results of specialists are less than the sum of the individual talents if they do not complement each other's abilities.

In product design engineering, each of the elements involved is necessary for the successful delivery of a good design to the manufacturing group. To slight the importance of any one element is to reduce effectiveness of its operation and to reduce the effectiveness of the whole. For any one group to consider itself more important than the others is to invite lack of co-operation with consequent loss in effectiveness of the offending group. Only when all the elements work together as a team, with each individual doing his share and receiving his share of recognition, will the complex whole reach the full efficiency that can be expected.

This teamwork element is difficult to attain. It requires understanding and individual effort. Its

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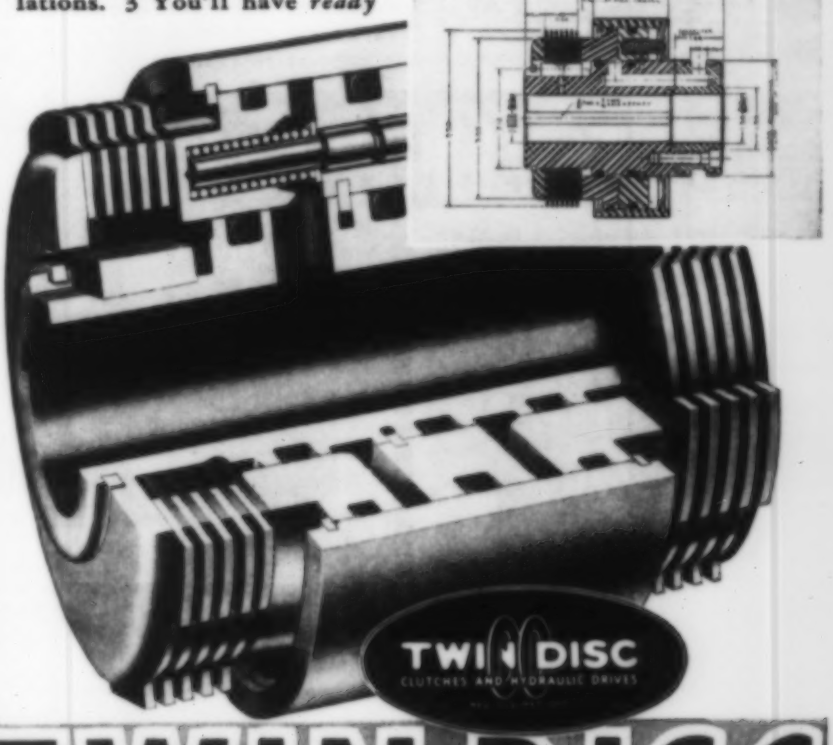

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—WILLIAM F. COLLINS
Chief Engineer, Product Eng. Dept., McCormick Works, International Harvester Co.

WHILE in this do-good spirit, and still trying to keep fresh resolutions untarnished, we want to share a letter with you. This, of course, is one that applies only to the other fellow.

To the Editor:

As usual, your editorial, "Encouraging Technical Competence," in MACHINE DESIGN, December, 1954, is pungent and thought-provoking.

You are so right—The average "engineer" here in the USA is not the "looked up to solid type citizen" found in Europe.

After many years of employing, working and associating with engineers, I have come to this conclusion: He has only himself to blame. With rare exception, every *successful* engineer I know (literally hundreds of them) *looks the part*. He is well dressed and emanates success.

"Clothes make the man," yeah, even the engineer! It rubs me raw every time I walk into an engineering department and see a collection of Bohemian fugitives from Greenwich Village—sport shirts in various stages of disrepair, baggy pants that haven't been exposed to an iron since they were bought (perhaps they may even be hand-me-downs), and the shoes—phooey—sandals, loafers, bedroom slippers, etc. They also save a lot of time by only shaving every other day or so!

Now how in the name of all that is holy can a guy expect to be "respected" if he looks like something the cat dragged in?

Engineers on the way up the ladder should take a real good look at the "whole" man at the top. Too often they merely envy the price tag he enjoys. You have to start practicing "success" long before you achieve it!

—JOHN C. SEARS
Executive Secretary, AGMA

Stress Relief

OUR final gem this month is comprised of some remarks made recently by Herbert Hoover under the appropriate title

Engineers

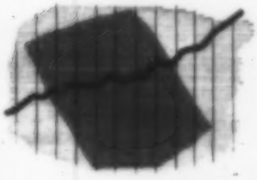
As indicative of the distance the engineers have risen in public repute, I might recall that some years ago while crossing the Atlantic I took my meals at the same table with a cultivated English lady. As we came into New York Harbor, at breakfast she said: "I hope you will forgive my dreadful curiosity, but I should like awfully to know what is your profession." I said that I was an engineer. Her involuntary exclamation was: "Why I thought you were a gentleman."

The engineer has the fascination of watching a figment of his imagination emerge with the aid of science to a plan on paper. Then it moves to realization in cement, metal or energy. Then it brings new jobs and homes to men. Then it adds to the security and comfort of these homes. That is the engineer's high privilege among professions.

The profession, however, does have woes. His work is out in the open where all men can see it. If he makes a mistake, he cannot, like the doctor, bury it in a grave. He cannot, like the architect, obscure it by trees and ivy. He cannot, like the lawyers, blame it on the judge or jury. He cannot, like the politician, claim his constituents demanded it. Nor can he, like the public official, change the name of it and hope the voters will forget. Unlike the clergyman, he cannot blame it on the devil.

Worse still, if his works do not work he is damned. That is the phantasmagoria which haunts his nights and dogs his days.

And the world mostly forgets the name of the engineer who did it. The credit goes to some fellow who used other people's money to pay for it. But the engineer, himself, looks back at the unending stream of goodness that flows from his successes with a satisfaction that few other professions can know.



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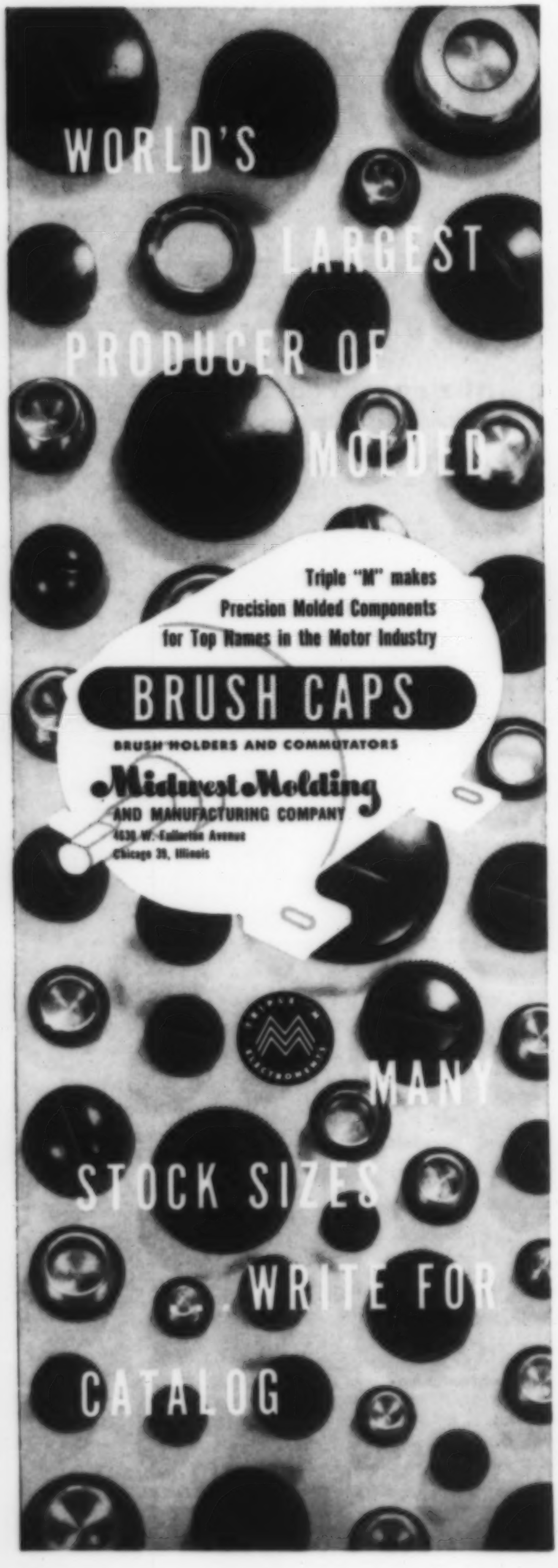

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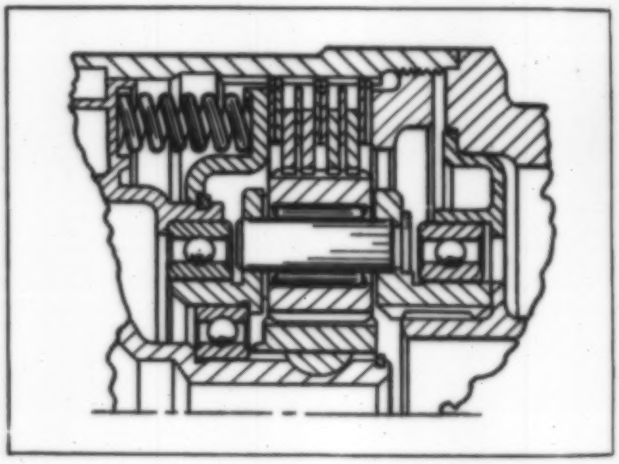
NOTEWORTHY

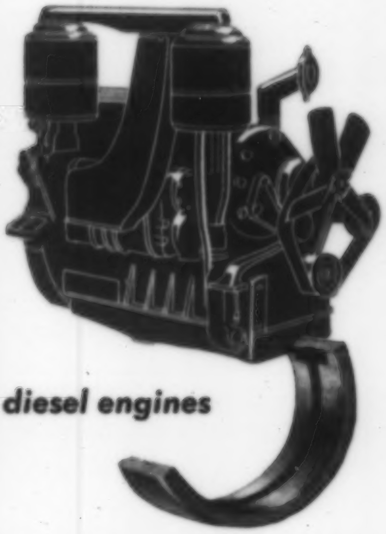
Patents

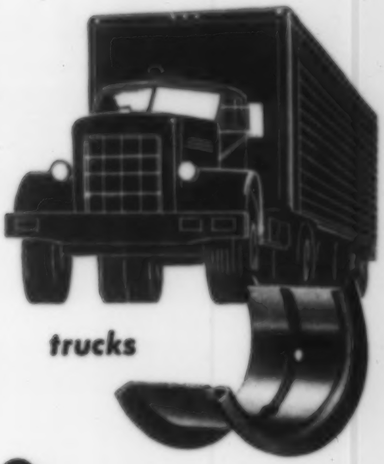
AUTOMATIC LOAD CONTROL for planetary gear sets consists of a lubricated friction-slip assembly—a spring-loaded stack of internally toothed steel disks alternated with externally toothed bronze disks. Each of the pairs of steel disks has a slightly different number of teeth. During operation, the resulting relative rotation between the disks generates heat, which rapidly reduces the viscosity of the lubricant to its normal operating value, and shears the lubricant off the disk faces. Thus, the ratio of breakaway torque to slipping torque is decreased almost immediately upon starting the unit. Limiting torque provided by the device can be made fairly uniform over a wide temperature range. *Patent* 2,679,170 *assigned to Jack & Heintz, Inc. by R. N. Prittie.*



ACCURATE LOCKING for retention and adjustable positioning of threaded members is obtained with a vernier type locking device. Designed for use on high-speed shafts, the device consists essentially of a collar, keyed to the shaft, and a flanged, threaded member in the form of a hollow-head bolt that screws into the end of the shaft. Rotation of the threaded member is prevented by a removable axial locking pin which is inserted into mating holes in the bolt flange and the collar, providing a secure locking connection. The number of holes in the flange and the collar differ by one, serving as a vernier arrangement to permit accurate adjustment of the angular

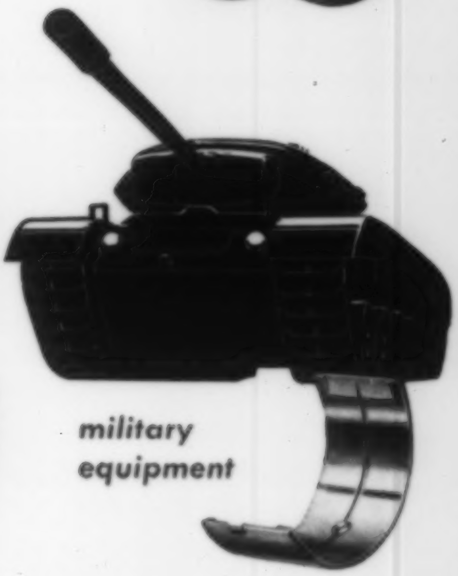
agricultural equipment


diesel engines


trucks

stationary and marine engines

automobiles


military equipment

earth-moving equipment

diesel locomotives

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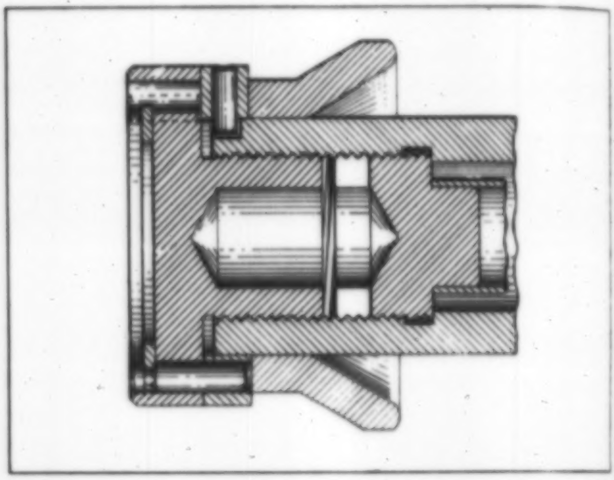
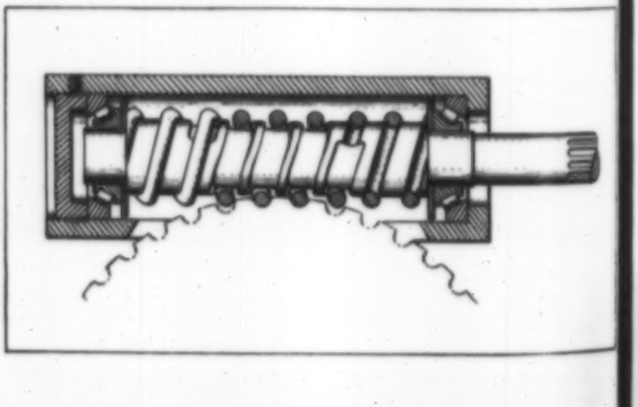
position and relative tightness of the threaded member. Retention of the locking pin is obtained by means of an internal snap ring which is in turn prevented from rotating by a dowel pin. *Patent 2,672,358 assigned to M. W. Kellogg Co. by O. A. Wienola.*



RESILIENT WORM GEAR consists of a helical spring wound around a shaft. Under normal load, the spring is nested in a spiral groove cut into the shaft. At overload, excessive axial deflection of the spring is prevented by a spiral ridge around the shaft. Backlash between the worm and sprocket is eliminated by having the axial pitch of the worm slightly different from the circular pitch of the sprocket. Wear is automatically taken up by the spring. *Patent 2,682,176 assigned to General Electric Co. by G. H. Fagley and W. E. Birchard.*



Copies of the patents briefed in this department may be obtained for 25 cents each from The Commissioner of Patents, Washington 25, D. C.

You can simplify purchasing . . . improve design . . . speed production

with improved C-D-F DILECTO® laminates

Only C-D-F, the Continental-Diamond Fibre Company, makes Dilecto laminated plastic, just as only Cadillac makes a Cadillac. Dilecto is 50 different materials with more combinations and variations in desired properties than we can tell you here.

But Dilecto has three important qualities that you should think about if you buy, design, or machine laminated plastics.

DILECTO HAS HIGH MECHANICAL STRENGTH

Mechanical strength is frequently an important determining factor in the selection of an insulating material. Insulating parts used in large electrical power equipment are frequently bulky. The high mechanical strength of Dilecto helps reduce size-dimensions of insulating parts without danger of failure. Instruments, meters and small motors frequently require very small insulating parts which must withstand comparatively large mechanical stresses. Insulation for use in high frequency circuits should have a minimum bulk factor for minimum dielectric losses. Dilecto fulfills these requirements with a combination of high mechanical strength and low loss factor, characteristic of the better C-D-F electrical grades.

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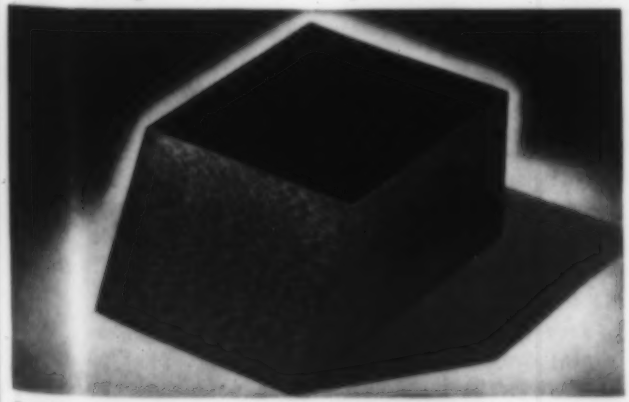
Both the base and the resin are good insulators by themselves. But C-D-F sells them to you in an improved, practical form . . . Dilecto. Uniform sheets, tight tubes, strong rods, close tolerance machined and formed specialties, high bond strength metal clads.

Why does Dilecto combine so well mechanical strength with dielectric strength and dimensional stability? Because Dilecto is almost homogeneous, a true blend of resin and base.

DILECTO IS ALMOST HOMOGENEOUS

A poor laminate absorbs moisture at its edges, loses its insulating properties fast. Entrapped moisture and other volatiles within the cured structure causes inconsistent dielectric strength, with ultimate puncture and breakdown.



Punch press and bench saw operators know how much time and material is saved when the laminated plastic is *uniform* and *homogeneous* in nature like Dilecto.

DILECTO IS IMPROVED

Yes, C-D-F Dilecto is an improved laminated plastic, due to high standards and advances in resin and manufacturing techniques. It is watched by skilled workers in our modern plants, checked against rigid standards . . . C-D-F standards . . . by our quality control people. It is easy to machine, and the C-D-F shops are doing a booming business in specialties.

Table I—Typical Improved Phenolic Laminates

Commercial designation[a]	Resin	Filler	Improved properties	Improvement due to:
MEC-5	Phenolic	Nylon fabric	Insulation resistance; moisture resistance	Filler
XXHV-2[b]	Phenolic	Paper	High dielectric strength parallel to laminations	Resin and manufacturing technique
CRD	Phenolic	Cotton mat	Better machining	Filler
XXXP-26[b]	Phenolic	Paper	Insulation resistance; moisture resistance	Resin and manufacturing technique
C-92	Xylenol[c]	Cotton fabric	Alkali resistance	Resin
CF	Modified phenolic	Cotton fabric	Postforming	Resin

[a] All grades are Continental-Diamond Fibre Company.

[b] Resins have improved penetrating properties and the manufacturing techniques use these properties to provide better impregnation of the filler. Since thorough impregnation eliminates entrapped moisture and air, greater moisture resistance and better dielectric properties are attained. Manufacturing techniques also provide suitable temperature control during the curing stage to assure uniform quality and optimum property values in the finished laminate.

[c] Xylenol is essentially a dimethyl phenol.

—from Electrical Manufacturing Article "Wider Design Opportunities with the NEW Phenolics", Part II.

The next time you think of laminated plastics, the name to remember is C-D-F Dilecto. The improved, high strength, uniform material that makes insulation buying and using more a science, less a puzzle. New grades, new applications, new savings are just part of the Dilecto success story. Look up the facts in Sweet's Design File, or write for catalog. Send us your blueprint for quotation . . . tell us your design dream . . . C-D-F wants to work with you.

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TWO-POLE MOTOR SWITCH

INSTALLS EASIER
WORKS BETTER
LASTS LONGER

Better Control and Protection for All Motors up to 1 HP

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Easiest to install and wire; removing wrap-around cover exposes mechanism completely, at front and both sides. Cover secured by single self-retained screw which cannot drop out and become lost. No annoying loose insulating baffle. Straight-through wiring; line terminals at top and load terminals at bottom . . . all clearly marked. Switch mechanism so compact it can be used in ordinary wall switch outlet box with standard toggle switch plate. Ideal for flush mounting on wall, panel or in machine cavity. Your Authorized Cutler-Hammer Distributor stocks both single pole and two-pole models of the new C-H 9101 Motor Switch. Order today and see the difference. CUTLER-HAMMER, Inc., 1310 St. Paul Ave., Milwaukee 1, Wisconsin. Associate: Canadian Cutler-Hammer, Ltd., Toronto.

EASY TO WIRE
Removing wrap-around cover opens switch at front and both sides.

OPEN TYPE 9101
Ideal for flush mounting on wall, on any panel or in a machine cavity.

CUTLER-HAMMER

CUTLER-HAMMER
MOTOR CONTROL
C-H

New Machines

Materials Handling

Fork Lift Truck: Operation in aisles as narrow as 6 ft is possible with model RSAT-3 Warehouser. This truck is equipped with extensible forks which reach beyond the outrigger wheels to pick up and deposit loads. Hydraulically operated, the forks slide forward 20 in. to provide 30 in. of effective length beyond the outrigger wheels. Since load is handled beyond the wheels, required underclearance is only enough to permit fork entry. Forks are retracted after loading to bring the load back against the fork carriage for transportation. Forks tilt automatically when load is raised to carrying height to provide stability during transit. Truck has rated capacity of 2500 lb at 15-in. load center, is 83 in. high overall and has 126-in. maximum fork lift. *Yale & Towne Mfg. Co., Philadelphia, Pa.*

Sectional Bag Conveyor: Heavy-duty unit designed for handling bags, boxes and cartons is available in 18 or 24-in. belt widths with standard 20-ft interlocking sections. Drive units are equipped with tail-shaft-mounted sprocket for powering driven units. Designed for fixed horizontal conveying, units can be adapted for portable or inclined conveying. Ends of carrying rollers are spun to form a smooth radius. Rollers turn in precision ball-bearing units protected by noncorrosive labyrinth seals. Standard roller spacing is 16 in., but decking is punched for variable spacing to meet requirements. Capacity is 200 lb per lin ft. *Stephens-Adamson Mfg. Co., Aurora, Ill.*

Metalworking

Lathes: Line of 12-in. swing lathes consists of four turret and four screw-cutting models. High strength of the lathes is distributed through wide gears, large shafts, heavy bearing supports, heavy base and at other points, resulting in high degree of power and smoothness and minimum vibration. Specifications include 12-in. swing over bed; 7¼-in. swing over saddle; 1⅜-in. spindle hole; 1-in. collet capacity; 23 and 35-in. centers. Variable-speed drive or standard double V-belt drive are optional on all models. Precision carriage rides on a two-V-way, two-flat-way bed that is sturdy, rigid, precision-ground and warp-free. Spindle turns on a double row of oversize ball bearings; no bearing adjustment is needed for any spindle speed. *Lathe Div., Logan Engineering Co., Chicago, Ill.*

Two-Way Bending Machine: Series 1400-A horizontal semiautomatic tube bending machine is designed for both clockwise and counterclockwise operations. It has an extended main spindle and double ways mounted on the top and bottom of both the stationary and swinging arms. The unitized head

TORQUE CAPACITIES

FROM

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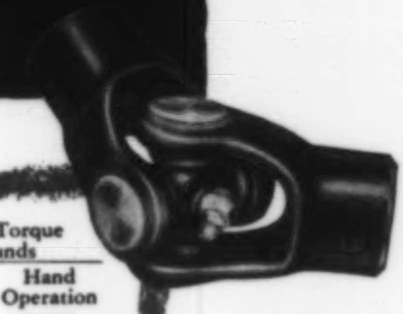

	Maximum Torque Inch Pounds	
K Series K2R Series	Continuous Load	Hand Operation
K-1-C	350	2,000
K-2-A	350	5,000
L6S Series L6N Series	400	2,000

	Recommended Torque Rating, Inch Pounds	Needle Bearings Optional
L10S Series	650	
1FR Series	1,080	"
L14S Series	1,230	"
3DR Series	1,800	"
L16S Series	2.200	"
L12N Series	3,300	"
L14N Series	6,000	"
35N Series	10,000	"

N Series	Recommended Torque Rating, Inch Pounds	Balanced for 3600 R.P.M. Max.
45N	14,000	
5N	20,000	"
50N	20,000	"
6N	38,000	"
60N	38,000	"
7N	57,000	"
70N	57,000	"
75N	70,000	"

	Maximum Torque Inch Pounds	
BW Series	Continuous Load	Momentary Load
BW-12	1,020	4,450
BW-1	1,695	7,500
BW-2	3,350	11,720
BW-3	4,450	16,800
BW-4	5,080	22,900
BW-5	8,640	34,200
BW-6	11,620	60,000
BW-7	28,600	150,000
BW-9	89,300	500,000

*Extra shock-load capacity built into all sizes.

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Need a moderately small universal joint on your next project — for a hand-operated control rod, for example? Blood Brothers has it! In fact, you can select from any of four Series — all widely used on farm implements, road and construction machinery, tractor steering assemblies, etc.

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For really heavy work, look at the BW Series — for transmitting up to 1,400 H.P. with momentary loads reaching 500,000 torque inch pounds! It's the largest commercial universal joint made — and Blood Brothers makes it.

Thus, when you specify Blood Brothers, you can select from a wide range of torque capacities . . . and be confident of top-quality universals that contribute dependability and smoothness to your product's performance.

For details, contact Blood Brothers, stating your specific problem. We'll be glad to cooperate with engineering suggestions.

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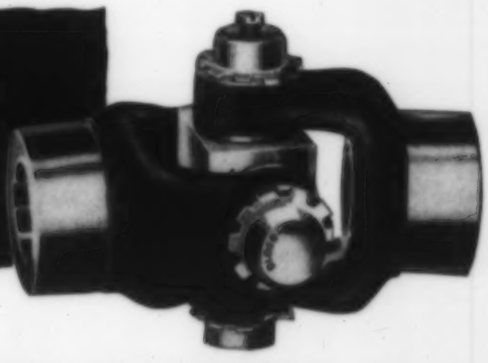

DIV.

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AND DRIVE LINE ASSEMBLIES

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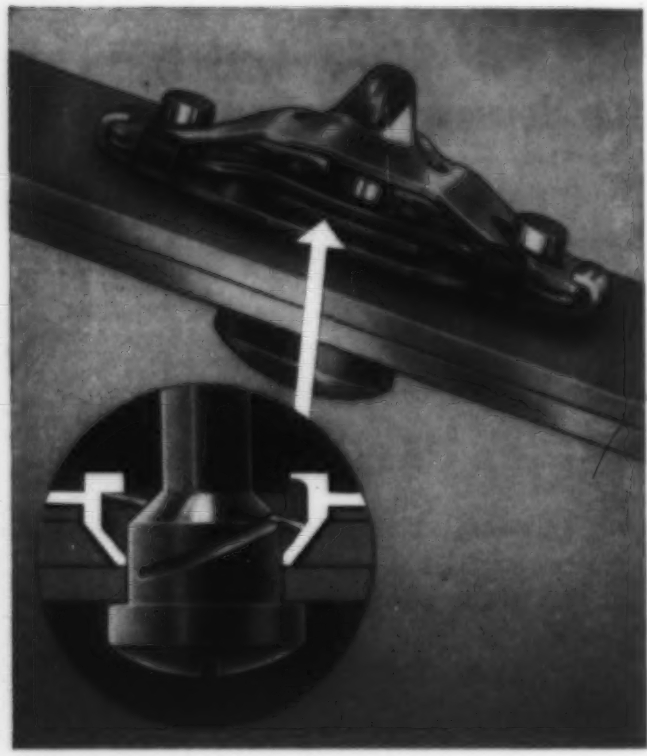
ALLEGAN, MICHIGAN



New Lion "Hi-Strength" fastener completely assembled. Cutaway shows the beveled counter sink. Beveling substantially increases the area over which stress is distributed.

NOW! Shear strength *twice* that of any other fastener!

NEW Lion "Hi-Strength" design fills every need for parts that must be fastened, taken apart and buttoned tight quickly

Here's a new and better answer to your problem of metal-to-metal fastening where high shear stress and vibration are factors.

It's the Lion "Hi-Strength" fastener, combining speedy quarter-turn opening and closing with a shear strength of 4750 lbs!

This "Hi-Strength" fastener is remarkably strong because shear load is distributed evenly over the area of the fastened parts. The secret lies in the *beveled* counter sink in the sheet and the nut. It's the same high shear principle used for years by the automotive industry for wheel lugs.

In addition to high shear strength, its tensile strength is 3000 lbs. Sheet separation is zero up to 4750 lbs. Misalignment is as much as .125 with high shear qualities. Regardless of the number of times it's opened or closed, there is no wear. It cannot be over-torqued, (up to 3750 lbs.). It cannot be fastened incorrectly. It is no larger than a standard No. 5!

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and top assembly is double-hinged to the base, which permits turning over the entire assembly 180 deg. Capacity of machine is 1 in. OD, 16-gage (0.062-in.) steel tubing; 1¼ in. OD, 16-gage (0.062-in.) copper tubing; or ⅝-in. diameter solid steel bar stock. Maximum standard radius, with rolling type pressure die, is 8½ in. Standard 5-ft tube length over mandrel can be extended. Normal operating pressure is 1000 psi. Typical production rate is 300 bends (150 pieces) per hour on 1-in., 16-gage steel tubing 4 ft long and requiring two 90-deg bends. *Pines Engineering Co. Inc., Aurora, Ill.*

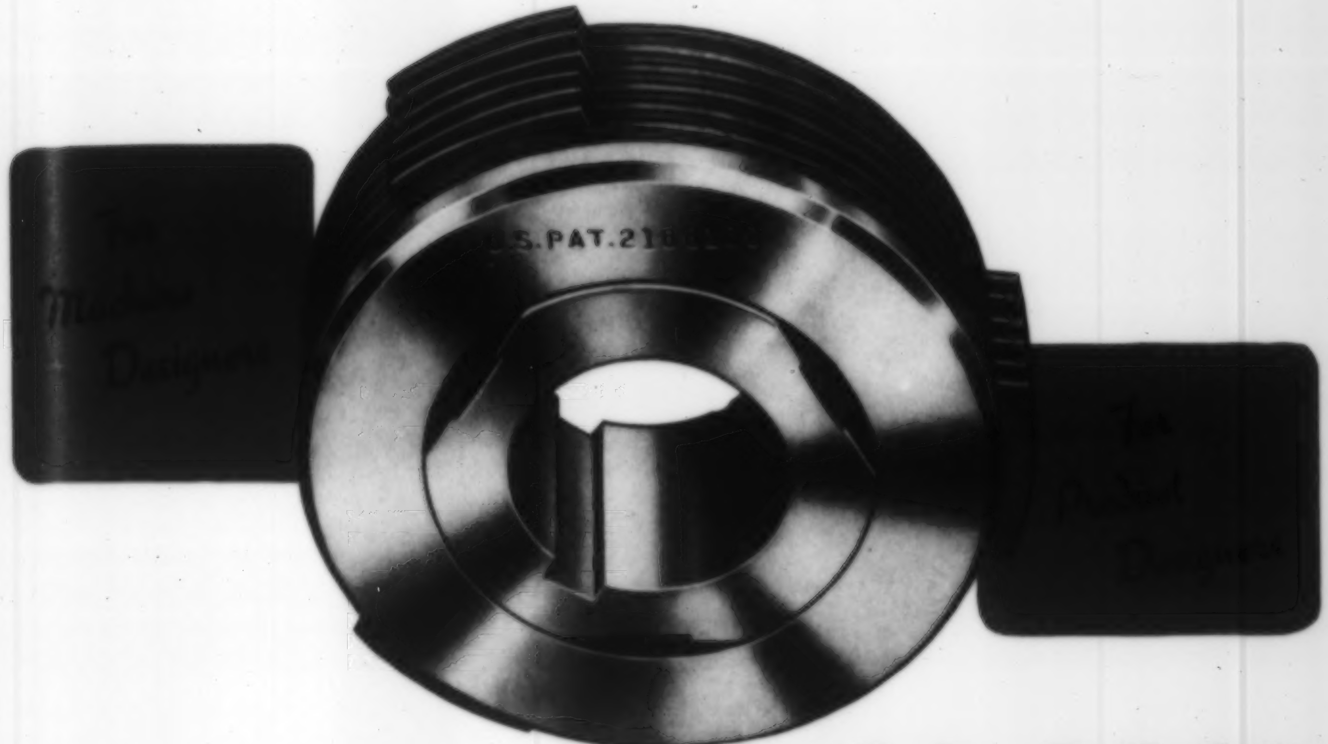
Decoiler and Shear: Shear line machine permits the use of coiled metal instead of flat sheets in production. Unit consists of hydraulic expansible-mandrel coil reel, roll straightener with power-driven rolls, hump table, high-speed shear, and conveyor type measuring and take-off unit. Various operations which are performed include decoiling, flattening, shearing and measuring the metal to required length. Steel or aluminum of 12 gage and lighter and up to 72 in. wide can be handled. Lengths can be cut to specifications with tolerances of 1/32-in. Variable speed range provides delivery of 50 to 150 fpm. Unit can also be equipped for edge trimming. *Dahlstrom Machine Works Inc., Chicago, Ill.*

Belt Grinder: Model 100 belt grinder for heavy-duty production grinding of ferrous and nonferrous castings, forgings and weldments is designed for wet grinding with a built-in coolant reservoir and coolant-collecting troughs. Powered for fast metal removal, grinder holds close tolerances. All bearings are ball or roller type and have seals to keep out grinding dust. Belts can be changed easily and quickly. Grinder has 2-hp, totally enclosed, three-phase motor and controls. *Ven Corp., Los Angeles, Calif.*

Packaging

Pneumatically Operated Carton Stapler: Model PA (portable air) carton stapler staples filled corrugated or fiberboard cartons from the outside. It uses staples with 1⅜-in. crown and ⅝ or ¾-in. legs. Large size permits spacing of staples 5 in. apart. Standard magazine capacity is 100 staples; magazine holding 200 staples is available. Machine operates on 50 or 60 psi line pressure, requiring 19½ cu in. per staple driven. It has an air lubricator and filter, fittings and 10 ft of hose. Measuring 11½ x 13½ x 4¾ in., it weighs 9½ lb. *Container Stapling Corp., Herrin, Ill.*

Plastic Sealer: Model 354 Ectromag magnetic bar heat-impulse sealer employs magnetic closing of a hinged pressure bar to provide secure clamping against side pull on the forming seal, as well as uniform pressure on all sealing operations. Standard seal length is 9 in.; units can be supplied for longer seals. Housed in a 12 x 12 x 4-in. cabinet, sealer is actuated by a foot pedal to close a hinged pressure bar to ¼-in., at which point a limit switch closes to complete the automatic cycle. The pressure bar is closed by the magnetic bar, and an adjustable auto-



ANNOUNCING THE NEW MAXITORQ **"DISC-PAC"**

A "DO-IT-YOURSELF" UNIT
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Patented Maxitorq Separator Springs that prevent drag, abrasion, and consequent heating in neutral . . . and the Maxitorq Locking Plate which locks all discs onto body . . . give you the outstanding features that are so highly favored by machine and product designers.

Thus you may build your own clutch or brake from our standard stock Maxitorq parts. The Disc-Pac keys to your shaft and is easily replaced. Units are available in 8-disc diameters from 2″ to 8″; ¼ to 15 h.p. at 100 r.p.m. . . . with 3 lugs on the smallest size, 8 lugs on the 3 h.p., and 12 lugs on the 5, 10 and 15 h.p. capacities.

The Disc-Pac fits Maxitorq standard Driving Rings in the event that you want to use them. As with the Maxitorq Clutch, all assembly, take-apart and adjustments are manual . . . no tools required.

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